THE STORYBOOK NUMBER COMPETENCIES INTERVENTION: LEARNING QUANTITATIVE VOCABULARY AND NUMBER SENSE THROUGH STORY READING

by

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ABSTRACT

Without providing effective, evidenced-based instruction during the early elementary years, children who come to school with low initial levels of mathematics and reading skills often continue to fall further behind their peers (Anderson & Nagy, 1992; Hart & Risley, 1995). However, educational interventions show promise for helping children develop language and mathematics skills in first grade and beyond (Cross, Woods, & Schweingruber, 2009; Marulis & Neuman, 2010). The present study hypothesized that a storybook reading intervention targeting specific quantitative vocabulary, such as “equal,” “before,” and “after,” would increase the children’s quantitative vocabulary and understanding of numerical relationships. Participants with low numeracy (N = 124) were recruited from kindergarten classes in four schools. Participants were randomly assigned to a quantitative vocabulary Storybook Number Competencies (SNC) intervention group, a number sense intervention group, and a business-as-usual control group. The interventions were carried out in small groups over 8 weeks (24 sessions). The SNC intervention introduced quantitative vocabulary words from *Common Core State Standards for Mathematics—Kindergarten*. The scripted lessons were based on storybooks with rich quantitative vocabulary not designed to teach mathematics. The lessons were modeled after the vocabulary sections of *Text Talk,* an evidence-based language arts curriculum (Beck & McKeown, 2001b). The current study demonstrated that a quantitative vocabulary intervention helped children with early numeracy difficulties to boost their quantitative vocabulary comprehension beyond their peers not involved in the SNC intervention. A remaining question is whether improved

quantitative vocabulary translates to improved mathematics outcomes for children with early numeracy difficulties.

Chapter 1

INTRODUCTION

Both early mathematics and reading skills are vital to building a foundation for children’s later academic successes. Without providing effective, evidenced-based instruction during the early elementary years, children who come to school with low initial levels of mathematics and reading skills often continue to fall further behind their peers and experience fewer instances of academic success later in life (Anderson & Nagy, 1992; Hart & Risley, 1995). However, educational interventions in pre-K and kindergarten show promise for helping children develop the necessary skills for learning vocabulary and mathematics in first grade and beyond (Cross, Woods, & Schweingruber, 2009; Marulis & Neuman, 2010).

In order to read successfully, children must be able to understand and use age-appropriate vocabulary (Dickinson, Golinkoff, & Hirsh-Pasek, 2010). For young children, vocabulary skills encompass comprehending and expressing the meanings of words (Coyne, Zipoli, & Ruby, 2006). Developing strong vocabulary knowledge during elementary school increases children’s chances of developing key reading comprehension skills in the middle and high school years (Cunningham & Stanovich, 1997).

Similarly, previous research has identified several complementary number competencies that have been shown to significantly affect later school mathematics outcomes (Jordan, Glutting, & Ramineni, 2010a; Jordan et al., 2006). Also referred to as number sense, most researchers agree that such number competencies involve elements of counting, number relations, and number operations (Jordan et al., 2006; Malofeeva, Day, Saco, Young, & Ciancio, 2004).

Low-income children typically come to school with weaknesses in both vocabulary and number sense relative to their middle-income peers (Anderson & Nagy, 1992; Hart & Risley, 1995; Jordan et al., 1994; Jordan et al., 2006). However, children from any socioeconomic background may face early numeracy and vocabulary difficulties due to their various paces and patterns of learning (Clements & Sarama, 2009). In particular, children with early numeracy difficulties have been shown to have difficulties understanding mathematics vocabulary separate from difficulties with general vocabulary (Toll & Van Luit, in preparation). Nonetheless, evidence suggests that it is possible for most children—regardless of their levels of reading and mathematics knowledge at kindergarten entry—to develop vocabulary and number competencies through receiving explicit assistance (Beck & McKeown, 2007; Dyson, Jordan, & Glutting, 2013; Jordan, Glutting, Dyson, Hassinger-Das, & Irwin, 2012). The present study used a quantitative vocabulary intervention to support students' development of the elements of number sense that include the ability to make judgments about numerical magnitude and determining properties of numerical relationships (Jordan et al., 2006).

Results from the first cohort (2009–2010) of a multi-year study[1] demonstrated that low-income, urban kindergarten students in an eight-week targeted number invention (e.g., activities involving counting, number knowledge, and number operations) attained

[1] Project Title: *Developing Number Sense in Children at Risk for Mathematics Learning Disabilities*, Funding Source: NICHD (5R01HD059170), Principal Investigator: Nancy C. Jordan

higher posttest scores on mathematics-related outcomes than their control group counterparts, relative to their performance on pretests (Dyson et al., 2013). In the second year of the study, a general vocabulary intervention was introduced as a contrast control to the number sense intervention. While children in the vocabulary intervention outperformed students in both the number sense and business-as-usual control groups on a vocabulary measure, the general vocabulary instruction did not affect students' number sense understanding (Jordan et al., 2012).

Since general vocabulary instruction did not affect number sense, the current study involved an intervention, referred to as the Storybook Number Competencies (SNC) intervention, that targeted specific quantitative vocabulary—words describing mathematical ideas and 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; Wynn, 1992). Many children's trade books provide ample opportunities to introduce rich quantitative vocabulary, and previous research suggests that storybook interventions may 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 mathematical knowledge (Hong, 1996; Jennings, Jennings, Richey, & Dixon-Krauss, 1992; Young-Loveridge, 2004).

In addition to addressing the needs of children at risk for academic difficulties, teachers in schools primarily serving children from low-income backgrounds face particular challenges due to a lack of resources, including time and materials. The SNC intervention sought to supplement the regular classroom curriculum by giving children a novel way to approach both mathematics and vocabulary learning without taking the focus away from their regular school curriculum.

The aim of the present study was to augment children's mathematics and vocabulary understanding by introducing an original intervention concept. A review of the literature revealed that to date no empirical studies that feature quantitative vocabulary in order to address both children's vocabulary and mathematical knowledge have been conducted. Several books—including *Cowboys Count, Monkeys Measure, and Princesses Problem Solve: Building Early Math Skills through Storybooks* (Wilburne, Keat, & Napoli, 2011) and *Read Any Good Math Lately?: Children's Books for Mathematical Learning, K–6* (Whitin & Wilde, 1992)—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 quantitative vocabulary or number sense. The present study examined a unique way to study how the connections between language and mathematics may improve academic outcomes for kindergarten students with demonstrated low mathematics knowledge.

Relationships among Mathematical Representations

Researchers' understanding of mathematical knowledge and thinking has changed significantly throughout the last several decades. From within the field of psychology, Skemp (1987) identified two types of mathematical understanding: instrumental (procedural knowledge; mechanical approach without deeper knowledge) and relational (conceptual knowledge; knowing what to do and why it is done). For the purposes of the current study, an examination of the research on children's development of vocabulary and mathematical skills through storybook reading led to a focus on relations among mathematical representations.

Mathematics research highlights the relational nature of learning new ideas and concepts (Van De Walle, 2007). 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). (See figure 1.1.) 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 wide variety of situations (Carpenter, Hiebert, & Moser, 1983; Gersten, Jordan, & Flojo, 2005).

Representations can be either non-symbolic (e.g., a group of five 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,

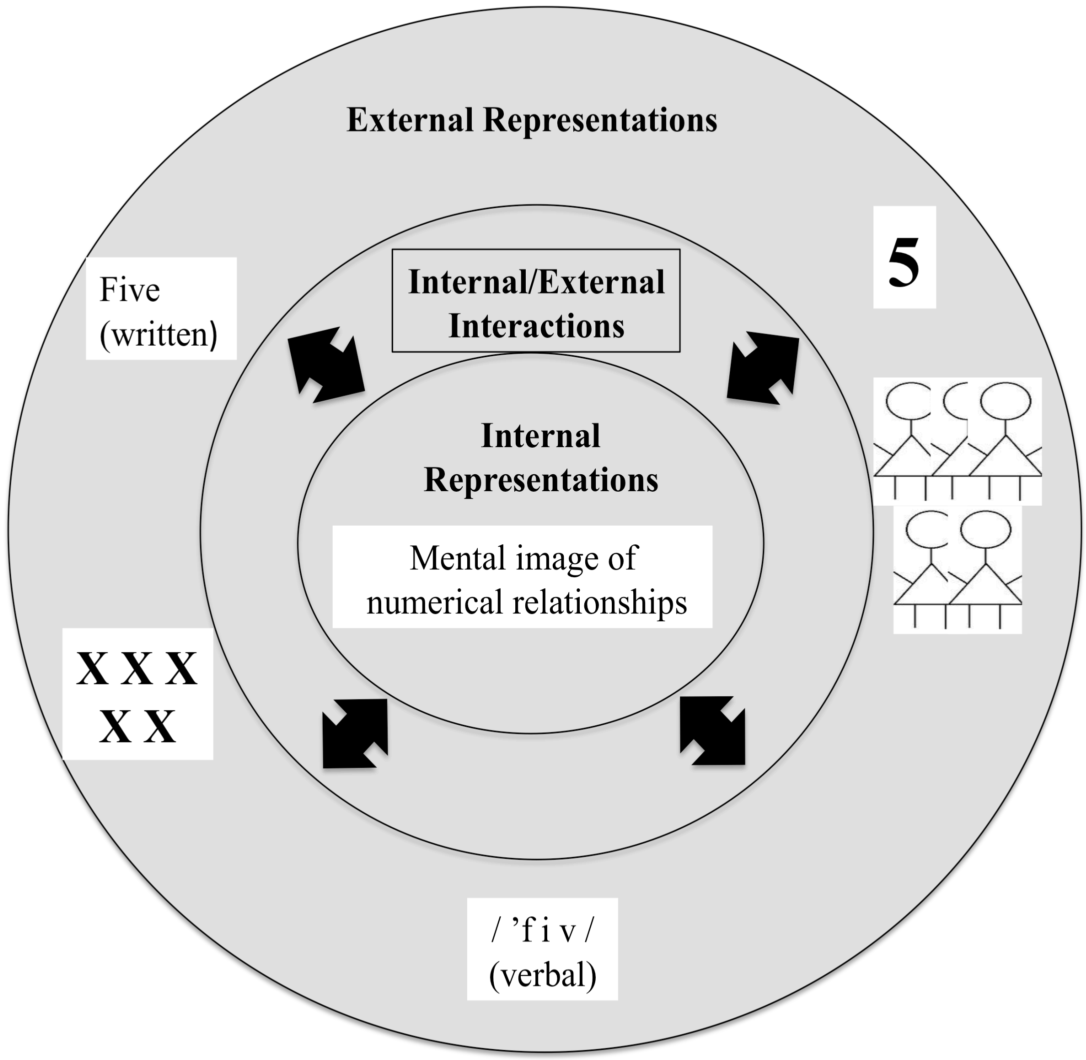

Figure 1.1. Children’s mental representations of numerical relationships (Pape & Tchoshanov, 2001)

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 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 quantitative thought processes beyond nonverbal representations (Mix, Huttenlocher, & Levine, 2002). Quantitative words help children discover commonalities between items by learning words for their attributes, such as number and size (Sandhofer & Smith, 1999; Waxman & Markow, 1995). Beyond the verbal representations of number, such as the word "five," children use quantitative vocabulary to represent numerical relationships. 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.

In their argument for the presence of a central mathematics conceptual structure that forms the foundation for quantitative thought, Case and colleagues (e.g., Case et al., 1996; Moss & Case, 1999) highlighted the importance of including multiple forms of mathematical representations in instruction. (See figure 1.2.) Case and colleagues (1996) proposed that children's quantitative thinking undergoes three developmental phases. From ages six to eight, children become proficient in the use of a single mental number line. During the next phase, children begin to use two mental number lines, such as comparing the ones and tens columns; however, they do not really understand how the two number lines relate. Then, by the time children are approximately ten years of age, they can understand and use upwards of two mental number lines. Later, children are able

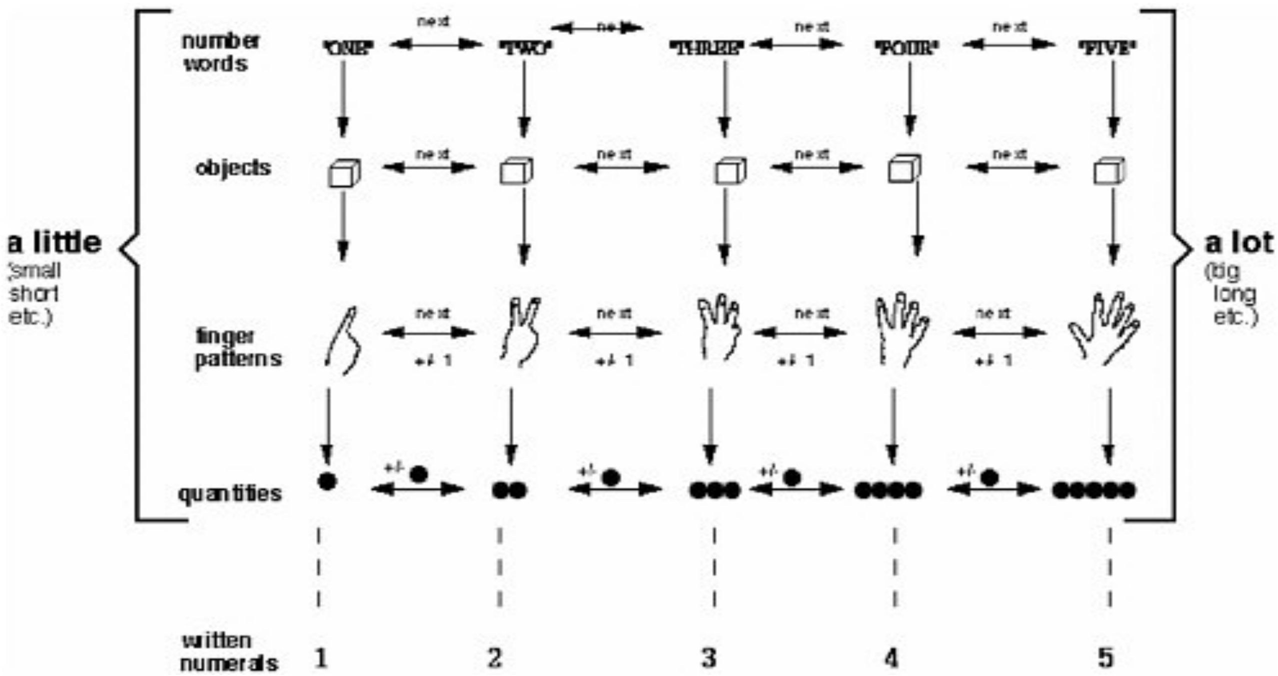

Figure 1.2. Central mathematics conceptual structure (Case, 1998)

to use their understanding of multiple mental number lines to compare numbers and solve number combinations.

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 functions to scaffold children's ability to build and refine their mathematics conceptual structures (Moss & Case, 1999).

Also in the area of instruction, the National Council of Teachers of Mathematics (2000) has advocated for all children to be able to understand and use various forms of mathematical representation. Understanding different representations involves comprehending the meanings behind all of the various depictions of one mathematical concept (Lesh, Post, & Behr, 1987). Curricula must present multiple representations of a single concept; for instance, the word “five,” the numeral “5,” and the quantity of five objects (Lesh et al., 1987; Pape & Tchoshanov, 2001). Also, an emphasis on the interconnected relationships among the various representations is vital to increasing children’s understanding of mathematical concepts, such as connecting the action of addition with the word “add” and the sign “+.”

By providing a framework for explaining numerical relationships, quantitative 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). These big ideas act in a variety of ways including: “provid[ing] a basis for understanding many concepts, supply[ing] a rationale for various procedures, and relat[ing] diverse concepts within and among domains [while] providing a basis for structuring knowledge” (Baroody, Feil, & Johnson, 2007, p. 125).

Development of Number Sense

Research has identified several related number competencies, referred to as number sense, that have been shown to 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) until 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).

Early number sense begins to develop during the preschool years (Clements & Sarama, 2007). Similarly to Case's (1998) central mathematics conceptual structure, number sense starts with children recognizing and counting small numbers and progresses to understanding number relations, including identifying numbers before and after other numbers on a number line. Next, children begin to perform addition and subtraction number operations. As they build their mathematical knowledge, children learn to count, compare, and manipulate larger numbers.

All three areas (counting, number relations, and number operations) of number sense are interconnected and iterative (Jordan, Fuchs, & Dyson, in press). By developing an understanding of the cardinality principle (i.e., the last number said represents the total amount of objects in a group) and one-to-one correspondence (Gellman & Gallistel, 1978), children begin to see the relationships between numbers on their mental number lines. In turn, children's mental number lines help them to solve number combinations by understanding that by moving up or down the number line, numbers get bigger or smaller. Also, children can employ counting to solve number operations by using their fingers to count on (i.e., child begins counting at four to find 3 + 5) or count all (i.e., child counts three fingers on one hand and five on the other) to find the answer (Baroody, Eiland, & Thompson, 2009).

Additionally, developing number sense requires that children understand several quantitative vocabulary words. Words such as “before,” “after,” “bigger,” “smaller,” “closer to,” “add,” and “subtract” all help children explain and describe numerical relationships and complete number operations (Jordan, Glutting, Ramineni, & Watkins, 2010b). An understanding of these quantitative vocabulary words gives children the crucial ability to manipulate number in ways that they could not before mastering the mathematics words.

Context also influences children’s development of number sense. As a result, Clements and Sarama (2009) developed the learning trajectories approach to teaching early mathematics, which notes that all children—particularly those with mathematics difficulties—do not develop at the same pace. Covering more than just the elements of number sense (e.g., measurement, shapes, and spatial thinking), the learning trajectories lay out progressions of developmentally appropriate mathematical skills and help teachers understand how to move students forward in their mathematical understanding based on their current developmental position (Clements & Sarama, 2009). In particular, the learning trajectories include a focus on helping children with mathematics difficulties gain a conceptual understanding of mathematical operations and relationships in the areas of counting, number relations, and number operations (Clements & Sarama, 2009).

Relationship between Language and Mathematics

Researchers continue to debate how children learn and understand the relationship between language and mathematics. To investigate this relationship, Gordon (2004) detailed his time with the Pirahã people in Brazil. The Pirahã have a “one-two-many” counting system where numbers greater than two are simply referred to as “many.” By interacting with the Pirahã, Gordon sought to find out whether they could conceptualize bigger numbers allowed by their language’s count sequence. As a result of informal research involving presenting individuals with counting tasks, Gordon asserted that some concepts—such as number—are incapable of being translated from one language to another, and such a situation might keep speakers of one language from grasping the untranslatable ideas of another. For example, Gordon asked several Pirahã to make the same-size grouping of objects—such as nuts or batteries—as he laid the objects before them on a table. As the sets surpassed their counting system, the Pirahã’s ability to replicate the objects decreased. As a result, he provided support for the notion that language and mathematical understanding are deeply interrelated.

Building on Gordon’s (2004) work with the Pirahã, other researchers have claimed that the reason that individuals from groups like the Pirahã cannot generate representations of exact number that transfer across different contexts is due to their lack of experience in social and cultural contexts that utilize such representations. Spaepen, Coppola, Spelke, Carey, and Goldin-Meadow (2011) sought to uncover whether “the absence of a linguistic model for representing exact number (in this case, a count list) could explain the difficulties Pirahã adults have representing large exact numbers” (p. 3163). The authors posited that the Pirahã’s issues might be explained by the lack of cultural opportunities to work with exact number. In order to examine such a possibility, Spaepen et al. (2011) studied Nicaraguan homesigners—deaf individuals without access to Nicaraguan Sign Language—who do not have number words in their language but live in a country where others use number words. They found that adult homesigners had difficulty generating exact values for sets larger than three.

If individuals whose languages lack counting words have trouble with number concepts, how do children from cultures with number understand number words and concepts? Research has suggested that children's knowledge of number words is generated through their knowledge of the relationships among various numbers. Speaking specifically to the creation of number concepts, Carey and Sarnecka (2006) proposed the idea that bootstrapping—in which language enables the creation of new, internal representations of concepts—aids in the creation of children's understanding of numerical concepts. Basically, children have rudimentary language knowledge from which they glean new information to build their understanding of language concepts (Carey & Sarnecka, 2006). The authors demonstrated the process of bootstrapping through the example of acquiring concepts for positive integers, such as 1, 2, 3, and so forth. Language helps children begin to construct meanings for numerical symbols, because number words act as placeholders for children to begin to build their meanings of natural number (Carey & Sarnecka, 2006). Therefore, it follows that the development of language often co-occurs with the emergence of natural number concepts. As such, Condry and Spelke (2008) found that natural number concepts develop as children figure out how number words relate to the counting routine.

Empirical Ties between Language and Mathematics

Empirical research also suggests that language proficiency is related to mathematics achievement. Related to Condry and Spelke (2008), several studies have investigated the relationship between children's number knowledge and number words (e.g., Huang, Spelke, & Snedeker, 2010; Le Corre & Carey, 2007; Slusser & Sarnecka, 2011; Wynn, 1992). In order to understand mathematical concepts, children must learn the language of mathematics, which includes specialized vocabulary. Therefore, for the purposes of the present study, this section focuses on studies that examined the effects of language development on mathematical abilities.

In preliminary research, Ramani, Hitti, Zippert, and Siegler (2011) examined how Head Start children's (63% English/Spanish bilingual) language abilities related to their mathematical skills. Children's language abilities were assessed using the *Peabody Picture Vocabulary Test-III* [PPVT-III] (Dunn & Dunn, 1997), while number skills were assessed with an author-created test consisting of items related to number line estimation, numerical magnitude comparison, and numeral identification. The authors found that the children who scored higher on the language assessment also scored higher than their peers on counting performance, numeral identification, and magnitude comparison tasks[2]. Language ability did not predict children's performance on the number line estimation test (e.g., "Where does N go on the number line?"), and as a result, Ramani and colleagues posited that number line estimation relates directly to children's number sense without being mediated by language ability.

Durand, Hulme, Larkin, & Snowling (2005) sought to determine cognitive skills that affect reading and calculation abilities in a group of seven- to ten-year-old children. Verbal ability (measured by listening comprehension, vocabulary, and verbal reasoning)

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[2] Throughout this review of the literature, effect sizes are listed if they were reported in the original studies.

and digit comparison were significant predictors of children's calculation abilities. Verbal ability also predicted children's reading abilities.

Similarly, LeFevre and colleagues (2010) examined three different cognitive pathways to early numeracy—quantitative, linguistic, and spatial—with children ranging from four to eight years of age over the course of the three-year study. The authors hypothesized that children's performance on vocabulary (PPVT-III) and phonological awareness (*Comprehensive Test of Phonological Processing* [CTOPP] (Wagner, Torgeson, & Rashotte, 1999)) would align with their understanding of number words. The authors found that the linguistic pathway was the only proposed pathway that predicted children's performance on all of the measured mathematics outcomes with the following statistically significant moderate semi-partial correlations: numeration (.54), calculation (.39), geometry (.41), and measurement (.32).

Other researchers have examined how children learn the mathematics words that contribute to number knowledge and skills (Halberda et al., 2008; Wynn, 1992). Wynn (1992) explored the idea that children use the context clues for number words in sentences to determine their meanings. She proposed that children as young as two years of age can make the connection that determiners—words that define the reference of a noun, such as "some," "all," and "both"—are related to quantification in order to help them determine the quantity of the noun in question (Wynn, 1992).

In a study with middle-class, English-speaking children (ages two to five years), Halberda and colleagues (2008) found that linguistic experience (as a function of age) and not counting ability influenced children's understanding of the word "most." After assessing children's counting ability, the researchers asked the children to look at pictures of red and blue crayons and identify if there were more red or blue crayons. The authors concluded that the older children had more experiences hearing others use the word, which led to their greater levels of understanding.

However, Barner, Chow, and Yang (2009) claimed that age does not affect children's understanding of quantifiers and determinants. Rather, children's understanding of quantifiers and determinants is related to their knowledge of number words (Barner et al., 2009). The authors stated that words such as "some" and "all" help children understand the semantics of number words in order to grow their overall math abilities (Barner et al., 2009).

Two recent studies explored the relationship between children's number knowledge and general vocabulary understanding. Purpura and colleagues (2011) investigated the specific relationship between preschool children's early numeracy and literacy abilities. They gave preschoolers from a range of socioeconomic status (SES) levels numeracy (*Preschool Early Numeracy Skills* [PENS] (Purpura, 2009); *Woodcock-Johnson III Tests of Achievement* [WJ-III]: Applied Problems and Calculation subtests (Woodcock, McGrew, & Mather, 2001)) and early literacy (*Test of Preschool Early Literacy Skills* [TOPELS] (Lonigan, Wagner, Torgesen, & Rashotte, 2007)) assessments at two time points spanning one year. When controlling for students' initial numeracy knowledge and nonverbal cognitive skills—as measured by the Copying subtest of the *Stanford-Binet* (Thorndike, Hagen, & Sattler, 1986)—Purpura et al. (2011) found that the Vocabulary subtest of the TOPELS uniquely predicted children's follow-up scores on the PENS and WJ-III Applied Problems subtest. Children's early numeracy skills were not shown be significantly related to phonological skills, which suggests a different relationship between pre-reading skills and number sense. (See LeFevre et al., 2010.)

Additionally, Negen and Sarnecka (2012) examined number word knowledge and general vocabulary understanding with preschool students from 2.6 to 4.9 years of age. By using the Give-N task (Wynn, 1992) to measure children's number word knowledge and the Picture Vocabulary subtest from the *Woodcock-Johnson II: Revised* [WJ-II: R] (Woodcock & Johnson, 1985) to measure expressive vocabulary and the PPVT-III (Dunn & Dunn, 1997) to measure receptive vocabulary, the authors found that children's expressive vocabulary knowledge related to their number word knowledge at a statistically significant level across two studies (Negen & Sarnecka, 2012). Children's receptive vocabulary knowledge also significantly correlated with their number word knowledge (Negen & Sarnecka, 2012). All of the correlations were significant, even when controlling for the age of the children, suggesting an alignment with the ideas of Barner and colleagues (2009).

Finally, studies have also suggested that oral language may affect mathematics knowledge in children's everyday experiences. In their study of non-randomly selected five-year-old Dutch children, van den Heuvel-Panhuizen and van den Boogaard (2008) investigated the effects of a non-mathematics focused children's storybook—*Vijfde Zijn* (Being Fifth)—on kindergarten students' mathematical thinking. Through qualitative analysis, the authors found that children's mathematics-related utterances supported the concept that children may be mathematically engaged by being read a picture book. The authors recorded various utterances, such as when the children made statements about the numerosity of collections with or without exact counting, including subitizing and estimation (van den Heuvel-Panhuizen & van den Boogaard, 2008). For example, they noted when children remarked on how many people/objects were featured on a particular page of the book (van den Heuvel-Panhuizen & van den Boogaard, 2008). The authors claimed that this effect occurs even when using children's storybooks have not been written to teach mathematics or specifically address mathematical elements, including number or shapes.

Effect of Low Initial Levels of Vocabulary/Mathematics on Later Outcomes

After beginning formal schooling, children with low levels of vocabulary and mathematics knowledge often continue to fall further behind their peers throughout the elementary grades (Biemiller & Boote, 2006; Jordan & Levine, 2009). Several studies have proposed that children's experiences with mathematics and vocabulary differ with levels of SES (e.g., Hart & Risley, 1995; Jordan, Huttenlocher, & Levine, 1992; Jordan & Levine, 2009; Klibanoff et al., 2006). In their 1995 study, Hart and Risley claimed that race/ethnicity, gender, and birth order did not affect children's vocabulary acquisition; instead SES was the main culprit behind differences in children's vocabulary knowledge. In the specific area of number operations, Jordan and colleagues (1992) found that children from lower SES backgrounds continue to have difficulty with verbal mathematics problem solving even after they have mastered nonverbal calculations. Examining teacher effects on mathematics knowledge, Klibanoff and colleagues found that, over the course of one school year, teachers' use of mathematics talk produced a small but significant effect on children's mathematics growth, $d = 0.21$, $p < .05$. Further research has found that mathematics talk is a stronger predictor of children's acquisition of number words than their SES backgrounds (Levine et al., 2011). This finding suggests that early intervention may be able to compensate for the deleterious effects of low SES on children's academic outcomes.

Similarly, research has demonstrated that number sense concepts can be effectively taught to most children, regardless of SES background or initial level of number sense understanding (e.g., Berch & Mazzocco, 2007; Chard, Baker, Clarke, Jungjohann, Davis, & Smolkowski, 2008; Clements & Sarama, 2008; Griffin, 2004; Dyson et al., 2013; Jordan et al., 2012; Ramani & Siegler, 2008; Starkey, Klein, & Wakely, 2004). Research in the area of vocabulary development has shown the same ability to build the knowledge of children who begin school with low levels of vocabulary knowledge (e.g., Biemiller & Boote, 2006; Coyne et al., 2004; Coyne et al., 2007; Coyne et al., 2009; Han et al., 2010; Justice et al., 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001). These findings are promising in that they demonstrate that children's initial levels of vocabulary and number sense knowledge do not need to define their ability to achieve later academic successes.

Theoretical Foundations of Vocabulary Instruction

Several researchers have examined methods of effective instruction in the area of vocabulary development. Yet, the vocabulary skills of children from low socioeconomic backgrounds are often still less receptive to intervention than their peers (Marulis &

Neuman, 2010). As a result, researchers puzzle over how to further refine effective vocabulary instruction to ensure that all students achieve academic success. The field of cognitive psychology contains several competing explanations of how to successfully generate student learning through instruction—chief among these are direct instruction and discovery learning (Mayer, 2004). Previous research has shown that a combination of direct instruction and guided discovery learning is more effective at increasing children's vocabulary knowledge than either approach used individually (Marulis & Neuman, 2010).

Constructivism and guided discovery learning. Discovery learning has its roots in constructivism—which is influenced by the cognitive and situative theories of learning (Anderson, Greeno, Reder, & Simon, 2000; Greeno et al., 1996; Piaget, 1970). Constructivism is a broad theory of learning that claims individuals construct new knowledge through experiences and build mental representations by engaging in active cognitive processing (Tobias & Duffy, 2009). Constructivism also highlights the role of situated learning in building knowledge of new concepts and procedures (Mayer, 2004). As a proponent of the constructivist theory of learning, Piaget (1970) envisioned that schools would provide students with a place to try out their own hypotheses without direct teacher input.

The constructivist perspective influences several different types of instructional approaches, but current study focuses on discovery learning. According to constructivism, individual differences make it impossible to teach every student using one standard form of instruction (Kirschner et al., 2006); therefore, discovery learning—

instructional situations where students gain an understanding of concepts without explicit direction (Alfieri et al., 2011; Resnick, 2010)— arose as an attractive alternative to teacher-dominated instruction.

However, pure discovery learning has not been shown to be effective, but guided discovery learning—which combines discovery learning with teacher input and assistance—has been shown to be a successful instructional technique (Alfieri et al., 2011). In guided discovery learning, guidance involves any support provided to a learner including materials, teacher input, and peer assistance (Wise & O'Neill, 2009). The concept of guided discovery learning is closely related to the process of scaffolding—which has evolved over time to include any type of assistance provided to students during the learning process (Putambekar & Hubscher, 2005). Scaffolding is often mentioned as a type of guided discovery learning (Wise & O'Neill, 2009). Both techniques utilize ongoing feedback during instruction to assess the educational needs of students (Clark, 2009; Putambekar & Hubscher, 2005).

In the domain of vocabulary instruction, dialogic reading and guided play exemplify the tenets of guided discovery learning by challenging students to form their own ideas about the new vocabulary words and then apply their knowledge of those words to novel contexts (Alfieri et al., 2011; Whitehurst et al., 1988). During dialogic reading, children are asked to explain a story in their own words, answer probing questions, and engage with the illustrations in the story all while receiving ongoing teacher assistance (Harris, Golinkoff, & Hirsh-Pasek, 2010; Whitehurst et al., 1988). Similarly, guided play taps into children's natural curiosity about a topic and utilizes adult support to help guide children's discovery of the goals of the curriculum (Hirsh-Pasek, Golinkoff, Singer, & Berk, 2009).

Information processing and direct instruction. The information-processing approach claims that individuals develop the capacity for more complex understanding of the world as their brains develop over time (Atkinson & Shiffrin, 1968). As an offshoot of this theoretical approach, direct instruction involves an instructor explaining the exact meaning of concepts and procedures (Kirschner et al., 2006). During vocabulary instruction, direct instruction takes the form of a teacher explicitly defining the target vocabulary words (Engelmann & Osborn, 1999).

The human cognitive architecture model provides a specific rationale for direct instruction by explaining the role of different types of memory during learning (Atkinson & Shiffrin, 1968; Kirschner et al., 2006; Mayer, 2004). (See figure 1.3.) When individuals store knowledge in their long-term memory, they are able to retrieve it and use it in a working memory—or conscious processing—capacity to transfer that knowledge to new contexts (Kirschner et al., 2006). From this perspective, the goal of learning is to help students store knowledge in their long-term memories for later retrieval and transfer to new situations (Kirschner et al., 2006; Mayer, 2004). However,

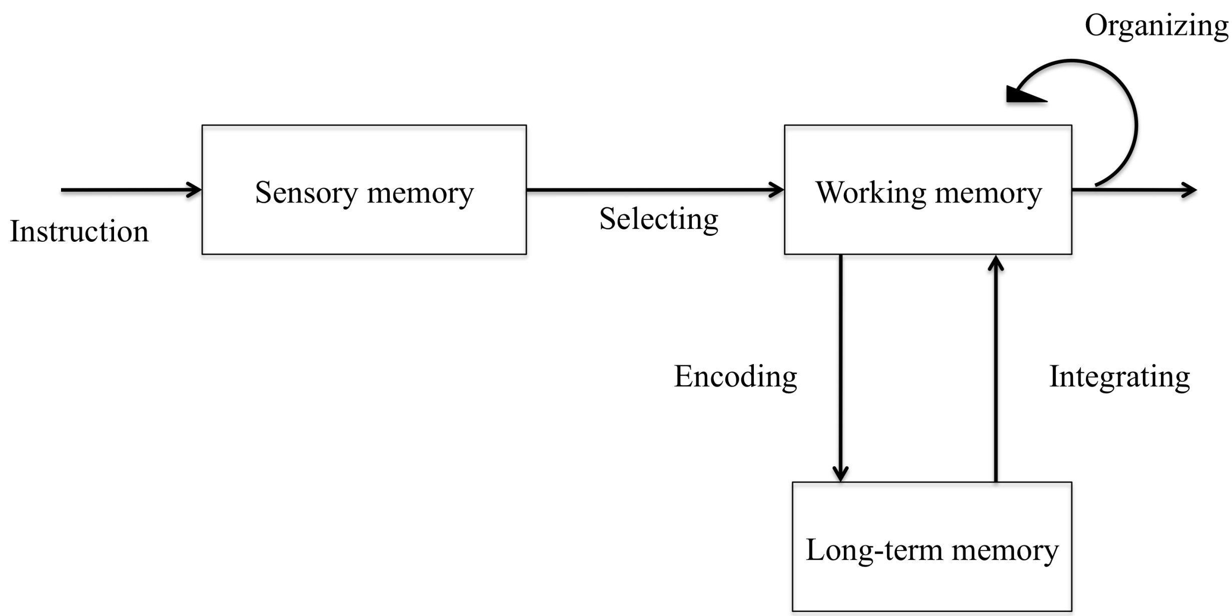

Figure 1.3. The learning process from the information-processing perspective (Mayer, 2004)

this approach has been criticized for not taking into account the individual characteristics of the learner and the educational context (Jonassen, 2009).

Definitions of learning. The constructivist and information-processing approaches have different definitions of learning. For interventions employing direct instruction, learning involves acquiring new skills and then transferring them to new situations (Atkinson & Shiffrin, 1968; Greeno et al., 1996). However, from the constructivist perspective, learning involves developing concepts and strategies for addressing novel problems in varied contexts (Greeno et al., 1996; Tobias & Duffy, 2009).

In spite of this, both the constructivist and information-processing approaches draw from the cognitive theory of learning, and as such, some agreement may be found. Both approaches look for students to be able to process information through mental conceptual structures that help them to build new understandings based on their previous knowledge (Greeno et al., 1996). Vocabulary intervention studies featuring both constructivist and information-processing instruction approaches often define success as both an increase in the number of words known and children's ability to transfer their knowledge of word meanings to new contexts.

Several experimental studies examining various academic content areas have used a combination of direct instruction and guided discovery with students from a wide range of ages and ability levels. The following section examines studies of preschool and early elementary students in order to argue for effective instructional methods for quantitative vocabulary development. Current research demonstrates that vocabulary instruction in elementary school is most effective when a combination of direct instruction and guided discovery learning (e.g., dialogic reading and guided play) is used.

Effectiveness of Storybook Interventions for Building Vocabulary Knowledge

In an effort to apply evidence-based instructional techniques, several studies have attempted to augment low-income children's vocabulary skills through a combination of guided discovery learning and direct word instruction (e.g., Biemiller & Boote, 2006; Coyne et al., 2004; Coyne et al., 2007; Coyne et al., 2009; Han et al., 2010; Justice et al., 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001). The combination instructional approach focuses on four main components of vocabulary education: direct instruction of word definitions; instructional scaffolding (teacher support); quality, ongoing feedback in an interactive learning environment; and guided play (Coyne et al., 2006; Han et al., 2010). In this way, 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). As a result of the combination instructional strategy, studies combining guided discovery learning with explicit word-meaning instruction showed statistically significant levels of receptive vocabulary gains over and above the performance of children in control groups or in other instructional conditions—including pure discovery learning and pure direct instruction (e.g., Biemiller & Boote, 2006; Coyne et al., 2004; Coyne et al., 2007; Coyne et al., 2009; Justice et al., 2005; Wasik & Bond, 2001).

Dialogic reading provides another way to introduce new words to children lacking in vocabulary knowledge (Whitehurst et al., 1988). During dialogic reading, instructors ask students to provide their own interpretations of storybooks and answer open-ended questions about story events and target vocabulary words (Whitehurst et al., 1988; Harris et al., 2010). Previous research suggests that children learn new vocabulary words from shared book reading when it is accompanied by extra-textual talk and questions and comments outside the book's text (Blewitt, Rump, Shealy, & Cook, 2009). By asking children to form their own ideas about the storybooks and apply their knowledge to new contexts, the dialogic reading approach embodies the tenets of discovery learning (Alfieri et al., 2011). In the combination approach studies, instructors practiced dialogic reading through the use of the CROWD strategy. The CROWD acronym represents: sentence **C**ompletion prompts, information **R**ecall prompts, **O**pen-ended (recalling information in students' own words) prompts, **W**h-word prompts (who, what, when, where), and **D**istancing (applying book content to other contexts) prompts (Whitehurst et al., 1994).

Additionally, when children are presented with explicitly defined words in varied contexts, they are likely to retain and transfer their new vocabulary knowledge to other situations (Harris et al., 2010). Therefore, by combining dialogic storybook reading with explicit instruction in word meanings in order to create a guided discovery learning environment, the vocabulary knowledge of children from low-income backgrounds has been increased in several studies (e.g., Biemiller & Boote, 2006; Coyne et al., 2004; Coyne et al., 2007; Coyne et al., 2009; Justice et al., 2005; Wasik & Bond, 2001).

In a study of low-income preschool children, Wasik and Bond (2001) tested the efficacy of dialogic reading and direct instruction. The authors assigned two classrooms to the intervention condition and two classrooms to the control condition. In the intervention, teachers were trained in the CROWD style of dialogic reading while control group teachers received no specific training. The study examined the effect of interactive shared book reading plus extension activities reinforcing the use of target vocabulary (Wasik & Bond, 2001). Four times a week for 15 weeks, the teachers read two storybooks to the children. At posttest, children who received the intervention performed significantly better on both an author-generated measure of receptive vocabulary featuring 44 intervention words and the PPVT-III than their control group peers (Wasik & Bond, 2001). As such, the authors claimed that the combination of direct instruction and dialogic reading generated greater levels of vocabulary learning than the use of book reading that did not incorporate explicit word definitions and dialogic principles.

Within a larger study of at-risk kindergarteners who were randomly assigned to a phonics intervention, dialogic storybook intervention (extended instruction), or control group, Coyne et al. (2004) compared a storybook group with a phonics group and a control group with regard to vocabulary knowledge. The storybook condition—also known as the extended instruction condition—involved instructors explicitly defining the target vocabulary words during an initial reading of the story where students engaged with the text. The definitions were simple, concise, and directly tied into the context of the storybook (Coyne et al., 2004). In true dialogic fashion, the initial interactive story reading was followed by several open-ended oral language activities based on the target words, during which instructors provided immediate feedback to student responses (Coyne et al., 2007). As a result of the integration of explicit vocabulary instruction and dialogic reading, the storybook group performed significantly better than both the phonics group and the control group on an author-generated test of receptive vocabulary (Coyne et al., 2004).

The authors also compared the storybook group with the control group to determine the effects of the intervention on children with low levels of receptive vocabulary at the initial PPVT-III pretest. The authors found that students with low receptive vocabulary increased their understanding through the explicit vocabulary instruction in the storybook intervention at greater levels than their counterparts with higher receptive vocabulary as well as children who did not receive storybook instruction (Coyne et al., 2004). As a result, Coyne and colleagues suggested that extended instruction might be one way to increase the chances of academic success for students at risk for reading difficulties. Since most differences in children's vocabulary knowledge occur before grade 3 (Biemiller & Slonim, 2001), finding that the combination of direct instruction and dialogic reading improves struggling children's vocabulary in kindergarten is key to addressing early disparities in word understanding.

In three later studies (e.g., Coyne et al., 2007; Coyne et al., 2009), Coyne and colleagues investigated the ability of extended instruction to increase low-income children's vocabulary knowledge. All of the studies focused on three components of vocabulary education: conspicuous instruction (direct instruction), instructional scaffolding (teacher support), and high-quality feedback in an interactive learning environment (Coyne et al., 2006). The 2007 study placed low-income kindergarten students into small groups within two research conditions using storybooks: extended instruction or incidental exposure. However, since the study was a within-subjects design, all students received instruction in both conditions. The extended instruction condition replicated the same condition from the 2004 study. In the incidental exposure condition, an instructor read the storybook to the children, but unlike the extended instruction condition, no definitions were given for the target words (Coyne et al., 2007).

To assess children's vocabulary understanding, the authors developed a receptive definitions measure that asked the children to identify six target words from the intervention. The employment of the combination instructional strategy provided children with more opportunities to be exposed to and understand the target vocabulary words. As a result, the children identified significantly more words on the author-generated assessment from the extended instruction condition than words from the incidental exposure condition (Coyne et al., 2007).

In a second study in the 2007 article as well as in the 2009 study, Coyne and colleagues introduced another research condition, embedded instruction, which was similar to extended instruction except that children were not given the same type of interactive activities after the book reading. In the 2007 study, the authors found that embedded instruction was not as effective as extended instruction in helping students learn target vocabulary words. The authors concluded that the added in-depth examination of target words in varied contexts helped extended instruction surpass the other treatment conditions (Coyne et al., 2007).

Likewise, in their 2009 work with low-income kindergarten students, Coyne and colleagues found that the effects of the treatment condition (incidental exposure, embedded instruction, or extended instruction) significantly affected children's performance on their receptive definitions measurement of vocabulary (Coyne et al., 2009). In both of the studies, children demonstrated greater levels of vocabulary understanding when instructed with extended instruction as opposed to both the embedded instruction and incidental exposure conditions.

Aligned with Coyne and colleagues' (2007, 2009) work, studies by Biemiller and Boote (2006) and Justice et al. (2005) demonstrated the potential effectiveness of embedded vocabulary instruction in comparison to incidental word exposure when an extended instruction condition was not included. In a pretest/posttest random assignment study with low-income kindergarten students in intervention and control groups, Justice and colleagues (2005) exposed children in the intervention condition to embedded instruction of vocabulary words for ten different storybooks over the course of a ten-week period. All children were pre/post tested on 60 target vocabulary words selected from the ten storybooks taught in the intervention. The intervention instructors provided explicit definitions for only 30 of the 60 vocabulary words. Children with initial low PPVT-III scores were placed into a low-vocabulary analysis group; within this group, children in the intervention condition performed significantly better at posttest on the explicitly taught words than controls (Justice et al., 2005). The researchers found no statistically significant difference between intervention and control group children on the non-explicitly taught vocabulary words. As such, the combination of direct instruction and dialogic reading again appeared to successfully increase children's vocabulary above and beyond other types of instruction.

Biemiller and Boote (2006) also showed that embedded vocabulary instruction in the context of book reading helped children learn vocabulary. With whole-class instruction in kindergarten, first grade, and second grade classrooms serving primarily children from working-class families, students were able to learn an average of 12% of word meanings through repeated storybook readings (incidental exposure), while adding embedded vocabulary instruction increased word learning to 22% (Biemiller & Boote, 2006). Children were pre/posttested in matched ability groups based on an author-generated general vocabulary assessment. Across all grades, the children receiving storybook instruction significantly improved their vocabulary word-learning rate over that of their peers who were not in the intervention (Biemiller & Boote, 2006).

The Justice et al. (2005) and Biemiller and Boote (2006) studies both reinforced

Coyne and colleagues' (2004, 2007, 2009) findings that embedded instruction—although not as effective as extended instruction—is more efficacious than incidental exposure to vocabulary words. Although not as robustly as extended instruction, embedded instruction still highlights the dialogic principles of interactive story reading by encouraging students to interact with the text as the teacher reads (Coyne et al., 2007; Coyne et al., 2009).

Finally, though not as extensively researched as other guided discovery approaches, guided play (Hirsh-Pasek et al., 2009), which involves adult scaffolding of children's activities to help them learn new vocabulary items, has also been shown to increase children's vocabulary knowledge. An intervention combining guided play with vocabulary instruction was shown to be effective in generating greater levels of vocabulary knowledge in preschoolers from low-income backgrounds than regular vocabulary instruction (Han et al., 2010). The authors divided children who performed at least one standard deviation below the mean on the PPVT-III into two groups: Explicit Instructional Vocabulary Protocol (EIVP) and EIVP + Play. EIVP included interactive book reading and explicit vocabulary instruction, similar to studies featuring dialogic reading and direct vocabulary instruction. However, the EIVP + Play condition added a guided play script where instructors engaged in dramatic play with the children. The play script gave the instructor directions to use props to help the child spontaneously explore the meaning of the new vocabulary words, such as pretending to bake a cake for the word "bake" (Han et al., 2010).

The children in the EIVP + Play condition demonstrated more growth in receptive vocabulary, as measured by the PPVT-III and a curriculum-based measure, than the children in the EIVP condition. However, the children in both conditions outperformed children who had received no tutoring. As such, Han and colleagues' work suggests that the addition of guided play to dialogic reading and direct vocabulary instruction further amplifies the effect of the combination instructional approach.

Roskos and Burnstein (2011) investigated another approach featuring guided play. They developed the "say-tell-do" technique, where instructors ask children to say the word, tell the meaning of the word, and produce a gesture that shows the meaning of the word (i.e., mimicking digging for the word "digging"). This sequence is followed by a guided play activity where children use the vocabulary words to reenact the story, play a board game, or creatively retell the story using props (Roskos & Burnstein, 2011). The children selected to receive the supplemental "say-tell-do" instruction or serve as controls scored at least one standard deviation below the mean on the PPVT-III. The "say-tell-do" group received three months of instruction. After the intervention, the authors found that the children in the intervention condition demonstrated more growth on the PPVT-III and a measure of the target vocabulary words than their control-group peers. As a result, the "say-tell-do" technique was touted as a promising method of vocabulary instruction for struggling students.

Broadly speaking, all of the combination direct instruction and guided discovery learning (e.g., dialogic reading and guided play) approaches showed statistically significant levels of vocabulary learning compared to the performance of children in control groups or other instructional conditions (Biemiller & Boote, 2006; Coyne et al., 2004; Coyne et al., 2007; Coyne et al., 2009; Han et al., 2010; Justice et al., 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001). As a result, the present study used a combination instructional approach for teaching quantitative vocabulary to students struggling with mathematical concepts.

Effectiveness of Storybook Interventions for Improving Mathematics Outcomes

Although several studies have examined the effectiveness of children's literature for boosting vocabulary understanding, none have specifically investigated the effect of using children's literature to address both vocabulary and mathematics understanding. However, some studies have used storybook reading to boost general mathematics achievement. Stories may provide a way to help students understand the different contexts that generate mathematics learning (Gary & Whitin, 1994). Jennings and colleagues (1992), Hong (1996), and Young-Loveridge (2004) each demonstrated that children's literature might be effectively used to promote mathematics learning with kindergarten students (≈ 5 years of age).

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. Young-Loveridge developed a pretest numeracy assessment that included questions assessing counting, pattern recognition, enumeration, numeral recognition, and addition and subtraction skills with concrete as well as imaginary objects. In addition to the content of the pretest, the posttest also included the pretest tasks as well as some additional tasks including items related to number facts, sequence knowledge, ordering sets and numerals, identifying one more than, enumeration span, counting on, understanding of more, multiple counting, writing numerals, and place-value understanding.

Children were randomly selected for the intervention group from the children performing in the lowest two-thirds on the numeracy measure (Young-Loveridge, 2004). The children in the intervention group attended sessions in pairs for 30 minutes each school day during a seven-week period, in addition to their regular language and mathematics instruction. The instructor and children read mathematically themed storybooks, played games, and completed author-generated counting activities related to the content of the stories. The intervention focused on " [children's] knowledge of number word sequences, accuracy, reliability and automaticity in using the enumeration process, experience with forming collections of particular sizes, and knowledge of stylized (spatial) number patterns and numerals" (Young-Loveridge, 2004, p. 86). The children in the business-as-usual control group received the regular New Zealand mathematics curriculum. The intervention program produced a significant increase in children's numeracy knowledge at posttest, $d = 1.99$, $p < 0.01$. Despite a substantial reduction in the initial magnitude of the effect size (from two standard deviations to 0.5 standard deviation), the effect of the intervention program was still statistically significant after 15 months at the final posttest, $d = 0.50$, $p < 0.05$. Young-Loveridge, however, could not determine whether the mathematics stories or the mathematics games made the difference in students' understanding of numeracy.

In the aforementioned study, the researcher only examined books that specifically addressed mathematical concepts. However, in a study of non-randomly selected, rural, Arkansan kindergarten students, 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 group as a result of five months of incorporating storybooks alongside the regular mathematics curriculum during whole-class instruction. The children in the experimental group were read storybooks and completed mathematically related activities including adding up the number of dolls that the giant would have after the children were given three dolls and the option to add five more. Children in the experimental group did not make significant gains on the more general *Metropolitan Readiness Test* [MRT]: Quantitative Operations and Quantitative Concepts subtests (Nurss & McGaurvan, 1986). Experimental group children used mathematics vocabulary in seven categories—comparison, time/money, position/classification, addition/subtraction, matching/patterns, number, and geometry/fractions/measurement—more frequently than their control group peers during free play after the completion of the study, although effect sizes were not reported.

Although the findings of Jennings and colleagues (1992) promoted the idea that children's literature can support children's efforts to learn mathematics, authors did not provide any data to demonstrate the staying power of the benefits beyond the end of the intervention program. Additionally, teachers of the whole-class intervention were randomly selected to participate in the study, but since no attention was given to how the children were placed in the classrooms, the study featured a quasi-experimental design.

The authors also did not detail how they determined teachers' and research assistants' fidelity of intervention implementation.

In a nine-week intervention study using random assignment with kindergarten students in either an experimental or a control classroom in Korea, Hong (1996) found that children involved in the experimental condition—mathematics-related storybook reading and games—scored significantly better on author-designed classification, number combination, and shape qualitative tasks than the control group children who were read nonmathematical storybooks. For example, the shape task required children to connect dots on 5 x 5 dot paper in order to make as many triangles and squares as possible. Children in the experimental group read storybooks based on weekly themes, such as "Family" which included the following concepts: size/seriation, measurement, spatial position, and number combination.

However, the author did not pre- and posttest the children with the same measure. Hong used the *Learning Readiness Test* as the pretest and the *Early Mathematics Achievement Test* as the posttest. The experimental group did not score significantly better than the control group on the *Early Mathematics Achievement Test*. The children in Hong's study were predominately from high SES families, and Hong posited 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 evidence to suggest that a storybook problem emphasizing number knowledge might be beneficial to children, but a need for further research arises in several areas. One study solely focused on books that were specifically written to address mathematical ideas (Young-Loveridge, 2004). Jennings and colleagues (1992) and Hong (1996) used children's storybooks that were not directed at mathematics learning; however, these authors did not address how the storybooks helped children develop both vocabulary and mathematics understanding. None of the studies explicitly examined the development of quantitative vocabulary. Additionally, two of the studies were conducted outside the United States in countries with different cultural contexts for mathematics and language learning (Hong, 1996; Young-Loveridge, 2004). None of the studies were comprised of the same population—primarily children from lower SES backgrounds with early numeracy difficulties—that the current study encompassed. These children are the most at-risk for language and mathematics learning difficulties. Finally, two of the three studies (Jennings et al., 1992; Young-Loveridge, 2004) did not implement random assignment to determine effects.

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 present study addressed the need for further research that examined how the development of quantitative vocabulary through the use of storybooks in children with demonstrated low numeracy understanding affects children's vocabulary knowledge and number sense.

Chapter 2

PRESENT STUDY

The present study is part of a four-year intervention project, funded by the National Institute of Child Health and Human Development (NICHD). The project is focused on developing number knowledge in kindergartners at risk for learning difficulties in mathematics. The goal of the present study was to test the effectiveness of Storybook Number Competencies (SNC) intervention on (1) children's quantitative vocabulary development, (2) number sense, (3) mathematics achievement, and (4) reading achievement. The majority of participants were children from high-risk, low-income backgrounds, but all participants needed supplemental instruction in mathematics. The study opened the door for the exploration of connections between vocabulary development and mathematics that may improve students' overall academic success.

Research Question

The overarching question of the study was:

> Does a storybook intervention that focuses on quantitative concepts result in gains in quantitative vocabulary, number sense, and general achievement, relative to a number sense intervention group and a business-as-usual control group?

It was hypothesized that:

1) Children in the SNC intervention group will significantly outperform the children in the number sense and business-as-usual control groups on a measure of quantitative vocabulary.
2) There will be no significant differences between the children in the number sense intervention and the children in the SNC intervention on measures of number sense and general mathematics due to the SNC intervention's inclusion of mathematics concepts.

Chapter 3

METHOD

Participants

One hundred and twenty four participants were recruited from 17 kindergarten classes in four schools in the same school district. Three of the schools served children from predominately low-income, minority families and one school served mainly middle-income families. Informed consent letters were sent home with every full-day kindergarten student. All consenting children 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.

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 90% of the study population. (See table 3.1 for detailed demographic information.)

At each of the four schools, one-third of the children were randomly assigned to the quantitative vocabulary (SNC) intervention group, the number sense intervention group (number sense), and the business-as-usual group (control). Group assignment (SNC, number sense, and control) also was stratified by kindergarten classroom. Each instructional group had four children and one instructor. With the exception of one school, the small groups were comprised of children who had different kindergarten teachers. At three of the schools, all of the small groups met at the same time (8:30 to 9:00 a.m. or 1:20 to 1:50 p.m.). In one school, the small groups occurred at various times (8:55 to 9:25 a.m., 11:35 a.m. to 12:05 p.m., 12:20 to 12:50 p.m., and 2:55 to 3:25 p.m.). In this case, some of the children in the small groups had the same kindergarten teacher.

By setting the $\alpha = .05$ with three groups and six covariates, 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

The measures assessed quantitative vocabulary knowledge, number sense, mathematics achievement, and reading achievement. A summary of the measures can be found in table 3.2.

Quantitative Vocabulary

The *Bracken Basic Concept Scale-Third Edition: Receptive* [BBCS-3:R]: Quantity subtest (Bracken, 2006a) assesses children's quantitative vocabulary knowledge. The BBCS-3:R was designed to measure children's understanding of basic language concepts from a range of content areas, including mathematics (Bracken, 2006b). 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, Sample items of the subtest can be

Table 3.1

Demographics by Group for Total Sample

	N	Gender		Ethnicity				Percent ELL[1]	Age as of Sept		Percent Low Income
		Male	Female	A	H	C	Other		Mean	SD	
SNC	42	18	24	4	27	10	1	57.1	64.74	3.67	93
Number Sense	42	26	16	9	26	7	0	54.5	64.62	3.51	88
Control	40	21	19	9	24	5	2	52.5	65.72	3.62	90
Total	124	65	59	22	77	22	3	54.7	65.02	3.60	90

Note: N = Number of participants, A = African American, H = Hispanic, C = Caucasian, Other = Biracial or Asian, ELL = English-language Learners, SD = Standard Deviation, SNC = Storybook Number Competencies intervention.[1] ELL students were identified by enrollment in bilingual classrooms.

found in table 3.3. 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 score 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 was used as 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 (α = .89).

Table 3.2

Measures

Construct	Measure
Quantitative vocabulary	*Bracken Basic Concepts Scale-Third Edition: Receptive:* Quantity subtest (Bracken, 2006a)
Number sense	*Number Sense Brief* (Jordan et al., 2010b)
Mathematics achievement	*Woodcock-Johnson III Tests of Achievement Normative Update Brief Battery/Form C* (WJ-III NU): Applied Problems and Calculation subtests (Woodcock et al., 2007)
Reading achievement	*Woodcock-Johnson III Tests of Achievement Normative Update Brief Battery/Form C* (WJ-III NU): Letter/Word Identification and Passage Comprehension subtests (Woodcock et al., 2007)

In order to determine the particular types of words that children learned, 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 (five items) and mathematics signs/symbols conceptual categories (two items) were examined, because they had the highest reliabilities (α = .70 and α = .73, respectively). The other conceptual categories had reliabilities below .70.

Number Sense

The *Number Sense Brief* [NSB] (Jordan et al., 2010b) is an untimed test that takes approximately 20 minutes to administer. Table 3.4 summarizes the areas assessed on the NSB, including counting, number recognition, number comparisons, nonverbal calculations, story problems, and number combinations. The items on the NSB are scored

Table 3.3

Description of the BBCS-3:R: Quantity Subtest: Conceptual Categories (Bracken, 2006b)

Concept Assessed	Concept Definition	Sample Test Items
Relative quantity	Quantities considered in comparison to other quantities	Examiner says, “Show me which tree has many apples.” Examiner says, “Show me where there are a few flowers.”
Volume	Amount of space occupied by an object	Examiner says, “Show me which box is empty.” Examiner says, “Show me which bowl is full.”
Comparatives/Superlatives	The similarities/differences between quantities	Examiner says, “Show me which child has more cake than the other child.” Examiner says, “Show me which farmer has the greatest number of chickens.”
Multiples	Consists of more than one component or object	Examiner says, “Show me which child has a double serving of potatoes.” Examiner says, “Show me where there are a dozen eggs.”
Fractions (includes part/whole)	A small part or piece of a larger quantity/ Relationship between a quantity and another quantity that includes it	Examiner says, “Show me which sandwich is cut in half.” Examiner says. “Look at all of the pictures. Show me a whole pizza.” Examiner says, “Show me where there is part of an orange.”
Mathematical signs/symbols	Mathematical operation symbols (e.g., +, –)	Examiner says, “Show me which sign means add.” Examiner says, “Show me which sign means subtract.”

Table 3.4

Description of the Number Sense Brief (NSB; Jordan et al., 2010)

Outcome Assessed	Outcome Definition	Sample Test Items
Counting skills and principles	Knowledge of the count sequence to at least 30, set enumeration, and stable order and one-to-one correspondence	Examiner says. “I’d like you to count as high as you can, but I bet you are really good at counting, so I’ll stop you when you’ve counted high enough.” “I would like you to count down or backwards starting from 14.”
Number recognition	Ability to name written symbols	Examiner says, “I am going to show you some numbers, and I would like for you to tell me their names: 4, 9, 13, 28, 37, 82, 124.”
Number comparisons	Ability to make numerical magnitude judgments	Examiner says, “What number comes right after 7? Which number is bigger, 5 or 4?”
Nonverbal addition/subtraction calculations	Instructor demonstrated number combination (addition/subtraction) problems	Examiner places two wooden dots in a horizontal line front of the child while saying, “See, here are two dots,” and then covers the dots with a cardboard check box lid. The examiner then puts out another dot and says, “See, here is one more dot; watch what I do,” and hides it under the same cover through an opening on the side of the box. The child is shown pictures of four sets of dots, each in a horizontal line, with different totals, and is asked to point to the set that has the same number of items that is hiding under the box.
Addition/subtraction story problems	Word problems that refer to objects numbering < 10	Examiner says, “Jill has two pennies. Jim gives her one more penny. How many pennies does Jill have now?”
Addition/subtraction number combinations	Orally presented problems involving addition or subtraction with numbers ≤ 10	Examiner says, “How much is 2 plus 1?”

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). The NSB in kindergarten is highly predictive of mathematics achievement in first through at least third grade (Jordan et al., 2009; Jordan et al., 2010a). The reliabilities for the NSB subareas, including counting ($\alpha = .74$), number recognition ($\alpha = .83$), number comparisons ($\alpha = .68$), nonverbal calculations ($\alpha = .45$), story problems ($\alpha = .66$), and number combinations ($\alpha = .82$), allow the interpretation of findings from all areas except nonverbal calculation.

Mathematics Achievement

The *Woodcock-Johnson III Tests of Achievement Normative Update Brief Battery/Form C* [WJ-III NU]: 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 quantitative 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 = ☐). For the ages of the children in the study, average internal reliability is high for both the Applied Problems ($r = .90$) and Calculation ($r = .97$) subtests (Woodcock et al., 2007).

Reading Achievement

Children's reading skills were assessed with the WJ-III NU: Letter/Word Identification subtest and the Passage Comprehension subtest (Woodcock, McGrew, &

Mather, 2007). In the Letter/Word Identification subtest, the test administrator asked children to identify one letter from a group of four letters, numbers, or pictures. Then, children were asked to identify whole words. The Passage Comprehension subtest required children to recognize pictures or words and recognize their relation to other pictures on the page. For the ages of the children in the study, average internal reliability is high for both for Letter/Word Identification ($r = .99$) and Passage Comprehension ($r = .96$) subtests (Woodcock et al., 2007).

Procedure

All children received their school's prescribed mathematics curriculum. While the other children took part in the interventions, the control group was involved in their classroom's regularly scheduled activities (e.g., specials or morning circle time). No group of children was pulled from their regular mathematics instruction time.

After administering the pretest over the course of two weeks in November of 2011, the interventions began in January of 2012. At the conclusion of the intervention, children were immediately posttested over the course of two weeks beginning on March 12, 2012. The delayed posttest was administered eight weeks after the immediate posttest, beginning on May 7, 2012.

The sessions were conducted with groups of four children per instructor for 30 minutes three times per week over the course of eight weeks. Children in both the SNC and number sense interventions attended, on average, 22 out of the 24 possible sessions (92%). For the SNC intervention, 13 children (31%) attended all 24 sessions. Twelve children (27%) who participated in the number sense intervention attended all 24 sessions. To gauge overall attendance during the intervention period, schools reported attendance for children from all groups for the 42 school days during intervention (January 9 to March 9, 2012). On average, children from all three groups attended 40 days of school during the intervention time period. Ten children from the control group attended the maximum of 42 days (25%), while 12 children (27%) of the number sense group and 11 children (26%) from the SNC group attended all 42 school days. Reasons for absences from the intervention included: absent for an entire school day, arrived late to school and missed the intervention time, and referred to the office for discipline issues.

Throughout the course of the study, two children from the SNC intervention, two children from the number sense intervention, and four control group children moved out of the school district or were dropped from the study due to missing 50% or more of the intervention sessions. As such, attrition was not a problem since 95% of the children in both the SNC and number sense groups and 91% of the children in the control group remained in the study from pretest to delayed posttest. The final analysis included 42 SNC children, 42 number sense children, and 40 control-group children.

Twelve trained education graduate or undergraduate students administered all of the measures and taught the intervention lessons. Training included practicing administering measures and lessons to fellow administrators. Instructors also attended weekly meetings to discuss lesson and measure administration. No instructors posttested the children they instructed, and testers were not aware of the children's group membership during pretesting, immediate posttesting, or delayed posttesting. Preliminary versions of the lessons were field tested in 2010–2011 and were revised in the fall of

2011.

Storybook Number Competencies Intervention

The SNC intervention introduced quantitative vocabulary words to reinforce number concepts related to counting, number relations, and number operations (Cross, Woods, & Schweingruber, 2009). The intervention drew from idea that mathematical information comes in multiple internal and external 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). In particular, the SNC intervention focused on how the language of mathematics contributes to the ways in which children understand number concepts. Beyond the verbal representation of number such as the word "five," children use quantitative vocabulary to represent numerical relationships. For instance, understanding and appropriately using the words "bigger" and "smaller" helps children elucidate the relationship between two numbers: 8 is bigger than 4, while 4 is smaller than 8.

Before selecting words for the intervention, different mathematics curricula for kindergarten were consulted, including: *Math Connects* (Altieri et al., 2009), *Math Trailblazers* (Teaching Integrated Math and Science Program, 2008), *Math Expressions* (Fuson, 2009), and *Math Triumphs* (Basich Whitney et al., 2009). The schools' language arts curriculum, *Journeys* (Baumann et al., 2011), was also reviewed to determine vocabulary words the children would learn during the course of the intervention.

Additionally, the *Common Core State Standards for Mathematics—Kindergarten*

(CCSS; Common Core State Standards Initiative, 2010), Mercer and Mercer's (2004) *Scope and Sequence Skills List* for mathematics in kindergarten, and Clements and Sarama's (2009) learning trajectories for early math were reviewed in order to further identify appropriate mathematics conceptual vocabulary. (See table 3.5 for examples of the intervention activities' alignment with the CCSS.) Children's performance on the BBCS-3:R Quantity subtest also was examined; of the 20 subtest words included in the SNC intervention, 80% of the words were known to fewer than 50% of children at pretest. After reviewing the various curricula, standards, and pretest scores, a total of 34 vocabulary words were selected. (See table 3.6 for a list of the storybooks and intervention words.) Finally, Karen Fuson, mathematics curriculum developer and professor emerita at Northwestern University, reviewed the words in order to ensure that they captured critical elements of number sense and aligned with the CCSS.

During the course of the intervention, children's progress was monitored with informal assessments each day—in the form of a review game played at the end of the session—and additionally during the third session associated with each of the seven books in order to address the individual needs of students. The final week of the intervention was dedicated to vocabulary review for all of the books.

Intervention Content

The lessons were based on seven different children's storybooks with rich quantitative vocabulary but not specifically designed to teach mathematics. A sample set of lessons is presented in appendix A. Instruction for each book contained three separate

Table 3.5

SNC Intervention Alignment with the Common Core State Standards

Common Core State Standards	Storybook Number Competencies Intervention
Counting and Cardinality	
Know number names and the count sequence.	
1. Count to 100 by ones and by tens	• Counting to 20 (*Snakes & Ladders* game; all books)
2. Count forward beginning from a given number within the known sequence (instead of having to begin at 1).	• Counting to 20 (*Snakes & Ladders* game; all books)
3. Write numbers from 0 to 20. Represent a number of objects with a written numeral 0–20 (with 0 representing a count of no objects).	• Writing numbers 1–9 (Book 3) • Writing numbers 1–9 (Book 4) • Blank Book activity (children draw own math stories) (Review week)
Count to tell the number of objects.	
4. Understand the relationship between numbers and quantities; connect counting to cardinality.	• Comparing the number objects to written numerals (Book 7) • I Have, Who Has game (identifying number of blocks and numerals) (Review week)
a. When counting objects, say the number names in the standard order, pairing each object with one and only one number name and each number name with one and only one object.	• Putting caps in order from 1–4 and children identify which caps go on before/after (Book 3) • Counting and comparing numbers of monkeys (Book 4) • Counting to identify sets with the least/greatest number of objects (Book 6) • *Chook Chook* book (counting objects 1–10) (Review lesson)
b. Understand that each successive number name refers to a quantity that is one larger.	• Identifying the number after (1–9) (Book 3) • Identifying quantities that are one more (Book 4) • *Chook Chook* book (counting objects 1–10) (Review lesson)
5. Count to answer "how many?" questions about as many as 20 things arranged in a line, a rectangular array, or a circle, or as many as 10 things in a scattered configuration; given a number from 1–20, count out that many objects.	• Counting numbers of monkeys (up to 10) in a group (Book 2) • Counting how many caps on the peddler's head (Book 3) • Counting and comparing numbers of monkeys (Book 4) • Counting to identify sets with the least/greatest number of objects (Book 6)

	• *Chook Chook* book (counting objects 1–10) (Review lesson)
Compare numbers.	
6. Identify whether the number of objects in one group is greater than, less than, or equal to the number of objects in another group, for example, by using matching and counting strategies.	• *It's Raining Cats and Dogs* activity book (counting and comparing groups of objects) (Book 1) • Dividing shapes into equal parts (Book 1) • Comparing two groups of objects to say which group is bigger/smaller (Book 2) • Counting to see if two groups of monkeys are the same in number (Book 2) • Counting sets to determine if one group has as many as another group (Book 6) • Counting to identify sets with the least/greatest number of objects (Book 6) • Comparing different numbers of objects to determine whether or not the groups are equal (Book 7) • *Chook Chook* book (counting and comparing objects 1–10) (Review lesson)
7. Compare two numbers between 1 and 10 presented as written numerals.	• Identifying the number after (1–9) (Book 3) • Identifying quantities that are one more (Book 4) • *Chook Chook* book (counting and comparing objects 1–10) (Review lesson)
Operations and Algebraic Thinking	
1. Represent addition and subtraction with objects, fingers, mental images, drawings, sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.	• +/– story problems with animals (Book 5) • Counting to determine if piles have enough objects to make 5 (Book 5) • Children designing own story problems (Book 5) • +/– story problems with animals (Book 6) • Children designing own story problems (Book 7) • Blank Book activity (children draw own math stories) (Review week)
2. Solve addition and subtraction word problems, and add and subtract within 10, for example, by using objects or drawings to represent the problem.	• +/– story problems with animals (Book 5) • Children designing own story problems (Book 5) • +/– story problems with animals (Book 6) • Children designing own story problems (Book 7) • Blank Book activity (children draw own math stories) (Review week)
3. Decompose numbers less than or equal to 10 into pairs in more than one way, for example, by using objects or drawings, and record each decomposition by a drawing or	• +/– story problems with animals (Book 5) • Children designing own story problems (Book 5) • +/– story problems with animals (Book 6) • Children designing own story problems (Book 7)

equation (e.g., 5 = 2 + 3 and 5 = 4 +1).	• Blank Book activity (children draw own math stories) (Review week)
Measurement & Data *Describe and compare measurable attributes.*	
1. Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.	• Measuring length in terms of number of objects in a line (Book 2) • Differentiating between parts of objects and whole objects (Book 1) • Stacking objects and determining big vs. small piles (Book 1) • Identifying groups of objects that have more/less than other groups (Book 7)
2. Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. For example, directly compare the heights of two children and describe one child as taller/shorter.	• Differentiating between parts of objects and whole objects (Book 1) • Stacking objects and determining big vs. small piles (Book 1) • Differentiating short vs. long lengths of monkeys (Book 2) • Identifying groups of objects that have more/less than other groups (Book 4) • Identifying groups of objects that have more/less than other groups (Book 7)
Geometry *Identify and describe shapes (squares, circles, triangles, rectangles, hexagons, cubes, cones, cylinders, and spheres).*	
1. Describe objects in the environment using names of shapes, and describe the relative positions of these objects using terms such as "above," "below," "beside," "in front of," "behind," and "next to."	• Identifying the position of caps on the peddler's head (before/after) (Book 3) • Drawing straight/long/short paths to school (Book 4) • Identifying pairs of objects (Book 7)
Analyze, compare, create, and compose shapes.	
2. Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners"), and other attributes (e.g., having sides of equal length).	• Comparing the same object in two different sizes to determine which is bigger/smaller (Book 2) • Comparing different size boxes to say which are bigger/smaller (Book 2)
Conventions of Standard English *Acquire and use vocabulary.*	
1. Determine or clarify the meaning of unknown and multiple-meaning words and	• Direct instruction of quantitative vocabulary words aligned with the CCSS and kindergarten

phrases based on kindergarten reading and content. a. Identify new meanings for familiar words and apply them accurately	mathematics curricula (all books) • Identifying and defining already-familiar words in mathematical contexts (i.e., before/after, bigger/smaller)
2. With guidance and support from adults, explore word relationships and nuances in word meanings. a. Sort common objects into categories (e.g., shapes, foods) to gain a sense of the concepts the categories represent. b. Demonstrate understanding of frequently occurring verbs and adjectives by relating them to their opposites (antonyms). c. Identify real-life connections between words and their use (e.g., note places at school that are colorful). d. Distinguish shades of meaning among verbs describing the same general action (e.g., walk, march, strut, prance) by acting out the meaning.	• Dialogic reading and direct quantitative vocabulary instruction (all books) • Pairing similar concepts in the same instructional section (all books)
3. Use words and phrases acquired through conversations, reading and being read to, and responding to texts.	• Dialogic reading, direct quantitative vocabulary instruction, and word-based activities (all lessons) • Cumulatively reviewing quantitative vocabulary words at the end of each lesson (*Snakes & Ladders* game; all books)

sessions, taking place over the course of three days and covering approximately six vocabulary words. Activities encouraged children to see how quantitative vocabulary words from storybooks related to the mathematics concepts (Foster, 2007).

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 in order to reinforce

Table 3.6

Storybooks and Vocabulary Words

Title	Author	Vocabulary Words
Two Greedy Bears	Mirra Ginsburg	Divide, Equal, Part/Whole, Piece, Bigger/Smaller, Half
McElligot's Pool	Dr. Seuss	With/Without, Same, Short/Long, Bigger/Smaller, Add
Caps for Sale	Esphyr Slobodkina	First/Second/Third, Above/Below, Before/After
Harold and the Purple Crayon	Crockett Johnson	Straight, Short/Long, None, More than/Less than, Left(over)
Olivia	Ian Falconer	Enough, Before/After, Closer to, Add/Subtract
Mike Mulligan and His Steam Shovel	Virginia Lee Burton	Some, As many as, Least/Greatest, Part/Whole, Add/Subtract
The Snowy Day	Ezra Jack Keats	Equal, Before/After, Add/Subtract, More/Less, Pair

children's understanding of the words in different contexts. Lessons featured activities using manipulatives—such as Monkeys in a Barrel—and worksheets that were both author-generated and borrowed from reproducible kindergarten resources.

Examples of instruction and activities from the lessons are described in the next section. (See table 3.7 for a description of key features across lessons.)

Sessions 1 and 2

The objective of sessions 1 and 2 of each lesson was for students to identify and

Table 3.7

SNC Intervention Lesson Components

Lesson Section	Component
Sessions 1, 2, and 3	Read the story • Dialogic reading technique engaging children with the text
Session 3	Vocabulary assessment • Children explain the words in the context of the story
Sessions 1 and 2	Introduce words/vocabulary instruction • 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
Sessions 1, 2, and 3	Direct mathematics instruction • Activities that apply the new words to mathematical contexts
Sessions 1, 2, and 3	Word-based activity • Guided play activities that apply the words to other contexts outside of the story
Session 3	Connecting the words to story comprehension • Children demonstrate an understanding of how the words relate to their comprehension of the story
Sessions 1, 2, and 3	Play *Snakes & Ladders* • Game reinforces vocabulary learned throughout the lesson(s)

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 interesting 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 briefly defining them. Next, the words were explicitly taught to the children. The words were described and defined within the context of the story. The following explanation of the word “add” comes from session 2 of *McElligot’s Pool* (Dr. Seuss, 1947): “In the story, the Dog fish scared the other fish when he swam toward them. If we add the fish together, we can find out how many fish were scared by the Dog fish. Add means combine together to make a larger amount.” 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, such as the following examples from *Olivia* (Falconer, 2000):

> Questions: The instructor asked the children different questions to gauge their understanding of the words. Example: “Why would Olivia want to add a scoop of ice cream to her bowl?”
>
> Opposites: The instructor provided an example of the new word and an example exemplifying the word’s antonym and asked the children to explain which example demonstrated the new word. Example: “If Olivia was really hungry, would she add more food to her plate or take away some food from her plate? Why?”
>
> Contextual examples: The instructor asked the children to build on the use of a word in the story and extend it to their own lives. Example: “We read about how Olivia gets ready in the morning, so let’s think about how we get ready for school in the morning. When I give an example of something you might

do in the morning, tell me something that you do before and after the activity: brush your teeth, get dressed, eat breakfast."

Manipulatives: The instructor provided the children with manipulatives to demonstrate the definition of the word from the story. Example: "In our story, Olivia really likes reading, so she asks her mom to read her more and more books. Let's practice adding our own books: 1 book + 1 book, 2 books + 1 book, 3 books + 1 book, 2 books + 2 books."

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, the direct mathematics instruction activities helped the children reinforce the key number sense concept(s) for the lesson. Each session only included one direct mathematics instruction activity to ensure that the focus remained on vocabulary but that the lessons still demonstrated how to use the words in mathematics contexts. For example, when learning about the words "add" and "subtract," the children completed an activity focusing on counting skills and number relations that involved creating story problems with animals. Lastly, the word-based activities used guided play to help the children understand how to use the words in other contexts. When reviewing the vocabulary words during the final week of the intervention, the instructor gave the children their own crayons and helped them to create their own storybooks using pictures representing the vocabulary words "equal," "part," "whole," "half," and "divide," thus transferring the meanings of the words outside the realm of any particular storybook. The instructor modeled the first picture by saying, "I had a dream that I baked one really big cookie. My sister saw it and ate half of it. Point to how much of my cookie is left. Now, each of you draw a picture about one of our vocabulary words. We will take turns telling everyone about our stories."

At the end of the session, the intervention groups played a word review game—*Snakes & Ladders.* (See appendix B for a sample of the game board and instructions.) The version of *Snakes & Ladders* used in the SNC intervention incorporates 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 as in the Great Race Game, *Snakes & Ladders* incorporates 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. For instance, the following question was asked about the word "equal": "Retell part of our story using our word 'equal.'" The game spinner features the numbers +1, +2, –1, and –2. Each player took a turn spinning the spinner and moving to appropriate square after counting following this example: The instructor says, "Suppose I was on number 3 on the board and I spun 2 on the spinner. I would say, 'I spun a 2,' since that's what I spun on the spinner. Then I would take my piece and move 2 spaces on the board, saying, 'I'm on

3. I'm going to move 4, 5.'" If the player landed on the bottom of a ladder, successfully answering the vocabulary question allowed him/her to advance up the ladder. If the player landed on the top of a snake, the player had to successfully answer the question; otherwise he/she had to slide down the ladder. The researcher designed the *Snakes & Ladders* game board.

Session 3

Session 3 for each book began with the instructor assessing the children's understanding of the vocabulary from the previous two sessions. The instructor asked the children to take turns retelling parts of the story and using the new words they learned in sessions 1 and 2. Afterward, the instructor read the story for a final time while highlighting how the vocabulary words related to comprehending the story by asking the children to explain their understanding of words in the context of the study. For instance, during *Olivia*, children were asked to explain what happened when Olivia wanted to add more books to her mother's reading list (her mother told her they could not read any more books). The sessions concluded with direct mathematics instruction and word-based activities and a round of *Snakes & Ladders*.

Number Sense Intervention

Based on the work of Dyson et al. (2013) and Jordan et al. (2012), the Number Sense intervention contained direct instruction aimed at improving children's number-sense-related counting, number relations, and number operations. For a more detailed description of the number sense intervention, see Dyson et al. (2013) and Jordan et al. (2012). The instruction in the number sense intervention did not include storybook reading and focused solely on explicit mathematics instruction and practice, instead of highlighting mathematics vocabulary.

Intervention Training

Undergraduate instructors were selected to participate in the study based on their completion of student teaching and strong recommendations from their student teaching coordinators. The scripts were presented to the student instructors in the fall of the school year along with the rationale for each activity. Participation in weekly group meetings helped prepare the instructors to administer the intervention. Pairs of instructors were observed while practicing teaching the lessons to each other in order to determine their competence in teaching the material. Suggestions for improvements and clarifications were shared during the group meetings in order to improve the lessons' structure and content. The group meetings also served as a space where instructors discussed behavior challenges and instructional issues that arose with individual students and intervention groups.[3]

Fidelity of Implementation

All instructors recorded each lesson in order to gauge their adherence to the intervention design. Later, three undergraduate research assistants checked the recordings against the intervention scripts in order to determine the level of fidelity of intervention implementation. The research assistants did not listen to their own recordings. The

[3] Originally, the BOSS (Shapiro, 2010) was to be used to assess each student from two SNC intervention groups (eight total students) six different times during the course of the intervention. However, one of the instructors declined to participate in the study immediately before the beginning of data collection, so the researcher taught an additional group and could no longer collect the BOSS data.

research assistants compared the recordings of all the instructors for eight randomly selected lessons out of the 24 (33%) to a check sheet of all of the activities. (A sample checklist can be found in appendix C). The check sheet required the research assistants to listen to each lesson and check off whether the instructor followed the script. Then, the research assistants totaled the number of checks for each instructor per lesson. After calculating totals for all of the lessons for each instructor, an average fidelity was determined for each instructor. Instructors demonstrated fidelity of implementation between 90.9% and 99.3%.

Chapter 4

DATA ANALYSES

Analysis Plan

An experimental pretest, immediate posttest, and eight-week delayed posttest design was used. Dependent variables were (1) quantitative vocabulary, (2) number sense, (3) mathematics achievement, and (4) reading 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. Although students in the study were nested within intervention groups and ANCOVA does not correct for intra-class correlation (ICC), defined as the proportion of group-level variance versus the total variance (Raudenbush & Bryk, 2002), the presence of non-significant ICCs suggested that there was no significant variance at the intervention group level. For each dependent variable, the pretest 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). Raw scores were used for all analyses. In addition to *p* values, effect sizes are reported using partial eta square coefficients (η^2). For partial eta square coefficients, values equal to or above .01 are considered small, values equal to or above .06 are considered moderate, and values equal to or above .14 are considered large (Murphy & Myors, 2004). Post hoc tests were conducted using the Bonferroni correction.

Chapter 5

RESULTS

Table 5.1 provides raw score means and standard deviations for the dependent variables (NSB, WJ-III NU mathematics total score, WJ-III NU reading total score, BBCS-3:R Quantity subtest, 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 *M*s and *SD*s are separated by pretest, immediate posttest, and delayed posttest. The mean percentile scores (based on national age norms) by group and time of testing are presented for the BBCS-3:R in table 5.2 and for the WJ-III NU in table 5.3.

Quantitative Vocabulary Analyses

Table 5.4 provides *p* values and effect sizes for analyses where BBCS-3:R Quantity subtest pretest total scores were used as the covariate. Although not significant at immediate posttest as originally predicted ($F(2, 120) = 2.484$, $p = .08$), the group means indicated a trend where the SNC intervention group knew a greater number of quantitative vocabulary words than their peers in the other groups. At delayed posttest, significant differences emerged between the SNC and the other groups, $F(2, 120) = 4.706$, $p = .01$, $\eta^2 = .07$. Post hoc tests revealed that the children in the SNC group significantly outperformed the children in the number sense intervention ($p = .05$) and the control group ($p = .05$) on the BBCS-3:R. Analysis of the SNC intervention words and conceptual category subareas on the BBCS-3:R provided a picture of gains on words specifically taught in the intervention along with two areas of the quantitative vocabulary: fractions (including part/whole) and mathematics signs/symbols.

SNC Intervention Words

Table 5.4 presents the intervention words pretest scores employed as a covariate. Unlike the BBCS more generally, this measure was closely aligned with the intervention. At posttest, there was a significant group effect, $F(2, 120) = 3.500$, $p = .03$, $\eta^2 = .05$. The SNC group outperformed the number sense group but not the control group, $p = .05$. At delayed posttest, there also was a significant group effect ($F(2, 120) = 6.063$, $p = .003$, $\eta^2 = .09$) with the SNC group performing significantly higher than both the number sense and control groups, $p = .01$.

Conceptual categories. The mean scores for the conceptual categories are displayed in table 5.1. At posttest, there was a significant group effect for words in the fractions conceptual category, $F(2, 120) = 3.099$, $p = .05$, $\eta^2 = .05$. However, post hoc tests revealed that significant differences existed only between the SNC group and the number sense group, ($p = .05$). At delayed posttest, there was also a significant group effect, $F(2, 120) = 10.541$, $p = .001$, $\eta^2 = .15$, demonstrating that the SNC group outperformed both the number sense group ($p = .001$) and the control group ($p = .001$). ANCOVAs using intervention concepts from the mathematics signs/symbols conceptual category revealed a significant group effect at posttest, $F(2, 120) = 11.204$, $p = .001$, $\eta^2 = .16$. Post hoc tests demonstrated that the SNC group outperformed both the number sense group ($p = .001$) and the control group ($p = .001$). At delayed posttest, the group

Table 5.1

Raw Score Means and Standard Deviations by Group and Time

Measures	Items	Pretest M	Pretest SD	Posttest M	Posttest SD	Delayed M	Delayed SD
NSB Total	45						
SNC		13.14	4.31	26.45	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	7.97	30.03	8.66
NSB Subareas							
Counting Skills	10						
SNC		3.90	1.59	6.45	1.74	7.19	1.68
Number sense		4.14	1.41	6.36	1.70	6.88	1.71
Control		4.35	1.12	6.45	1.67	7.45	1.48
Number Recognition	8						
SNC		1.55	1.09	4.98	2.07	5.45	2.12
Number sense		1.86	1.64	5.43	2.50	5.67	2.47
Control		2.17	1.44	5.20	2.07	5.70	1.95
Number Comparisons	9						
SNC		3.43	1.47	6.45	1.99	6.33	1.57
Number sense		3.86	1.62	6.50	2.14	6.12	1.94
Control		4.07	1.46	5.95	1.71	6.00	2.18
Nonverbal Calculation	4						
SNC		2.69	1.12	3.02	0.97	3.45	0.88
Number sense		2.50	1.25	3.02	0.92	3.43	0.77
Control		2.78	1.12	3.20	1.04	3.30	0.89
Story Problems	5						
SNC		0.88	0.92	2.02	1.57	2.40	1.75
Number sense		0.64	0.89	3.36	1.78	2.86	1.77
Control		0.62	0.87	1.88	1.57	2.55	1.76
Number Combinations	9						
SNC		0.69	1.14	3.52	2.93	5.21	2.89
Number sense		0.73	1.11	4.59	2.99	4.95	2.95
Control		0.75	1.24	3.75	2.87	5.03	3.16

BBCS-3:R Quantity	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
SNC 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	0.31	0.12	0.39	0.21	0.56
Control		0.03	0.16	0.15	0.48	0.15	0.43
WJ-III NU Math Total							
SNC		8.92	4.01	13.67	6.07	15.42	6.32
Number sense		9.17	2.17	17.75	4.71	18.42	5.20
Control		9.45	1.97	14.64	3.41	17.27	3.41
WJ-III NU Reading Total							
SNC		18.79	4.69	27.36	6.54	31.48	8.35
Number sense		19.00	5.65	29.12	7.98	32.81	9.56
Control		20.58	4.60	29.50	6.42	35.90	9.01
WJ-III NU Applied							
Problems		8.31	2.91	11.31	2.72	12.17	2.64
SNC		8.36	2.54	11.38	2.47	11.79	2.66
Number sense		8.72	2.18	11.10	2.23	12.20	1.84
Control							
WJ-III NU Calculation		0.33	0.90	3.05	2.51	4.76	3.14
SNC		0.29	0.92	4.64	3.57	5.12	3.44
Number sense		0.43	0.71	3.10	1.98	4.40	2.79
Control							
WJ-III NU Letter/Word							
Identification							
SNC		12.76	3.54	19.50	4.19	22.19	5.20
Number sense		12.40	4.67	20.09	5.19	22.24	6.19
Control		14.35	3.52	20.83	4.67	24.55	5.90
WJ-III NU Passage							
Comprehension							
SNC		6.02	2.11	7.86	3.02	9.29	3.99
Number sense		6.60	2.49	8.60	2.82	10.57	3.77
Control		6.23	2.17	8.68	2.46	11.35	3.60

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

Table 5.2

Percentile Rank Means and Standard Deviations on the BBCS-3:R Quantity Subtest by Group and Time

Group	Pretest		Posttest		Delayed	
	M	SD	M	SD	M	SD
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

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

effect held, $F(2, 120) = 8.622$, $p = .001$, $\eta^2 = .13$, with the SNC group still outperforming both the number sense ($p = .01$) and control groups ($p = .001$).

Overall, the children in the SNC intervention demonstrated clear quantitative vocabulary gains relative to the children in the number sense and control groups by delayed posttest on both the overall quantitative vocabulary subtest and a subset of closely aligned intervention words. Analyses of specific vocabulary categories of words showed that the children in the SNC group made gains in fractions and mathematics signs/symbols.

Number Sense Analyses

Table 5.5 provides *p* values and effect sizes for analyses where NSB pretest total scores were employed as the dependent variable. The SNC children did not show gains relative to the other groups in any areas.

Table 5.3

Percentile Rank Means and Standard Deviations on the WJ-III NU Subtests by Group and Time

Subtests	SNC		Number Sense		Control	
	M	SD	M	SD	M	SD
Applied Problems pre	30.21	25.50	31.05	22.50	31.35	21.45
Applied Problems post	46.81	24.83	46.18	23.04	42.53	20.77
Applied Problems delayed	47.62	24.49	42.10	22.75	46.68	20.16
Calculation pre	3.76	17.02	5.09	18.83	7.88	20.77
Calculation post	44.31	34.88	56.55	37.64	47.40	31.61
Calculation delayed	55.07	30.53	56.24	30.67	51.83	27.08
Letter/Word Identification pre	44.29	18.82	41.76	22.54	51.72	18.01
Letter/Word Identification post	61.00	20.61	63.38	21.12	67.18	16.71
Letter/Word Identification delayed	62.81	20.39	60.86	24.63	70.98	18.18
Passage Comprehension pre	50.26	27.44	55.31	26.99	49.40	29.53
Passage Comprehension post	54.43	22.05	61.21	19.75	63.60	13.90
Passage Comprehension delayed	53.14	25.20	62.10	18.84	65.95	18.10

Note: SD = Standard Deviation, WJ-III NU = Woodcock Johnson III, SNC = Storybook Number Competencies intervention, M = Mean, SD = Standard deviation

Table 5.4

ANCOVA Results Evaluating Intervention Effectiveness with BBCS-3:R Pretest Raw Scores as Covariate

Dependent Variable	Covariate		
	Total BBCS-3:R Pretest		Post Hoc Tests
	p	η^2	
Total BBCS-3:R post	*ns (.08)*	--	
Total BBCS-3:R delayed	.011	.07	SNC > Control*, SNC > NS*
	Intervention Words Pretest		Post Hoc Tests
	p	η^2	
Intervention Words post	.03	.06	SNC > NS*
Intervention Words delayed	.003	.09	SNC > Control*, SNC > NS**
	Fractions Pretest		Post Hoc Tests
	p	η^2	
Fractions post	.04	.05	SNC > NS*
Fractions delayed	.001	.15	SNC > Control***, SNC > NS***
	Math Sign/Symbols Pretest		Post Hoc Tests
	p	η^2	
Math Signs/Symbols post	.001	.16	SNC > Control***, SNC > NS***
Math Signs/Symbols delayed	.001	.13	SNC > Control***, SNC > NS**

Note: *p < .05, **p < .01, ***p < .001, NS = Number Sense Intervention, SNC = Storybook Number Competencies Intervention

Table 5.5

ANCOVA Results Evaluating Intervention Effectiveness with NSB Pretest Raw Scores as Covariate

Dependent Variable	Covariate NSB Pretest		Post Hoc Tests
	p	η^2	
NSB Total post	*ns*	--	
NSB Total delayed	*ns*	--	
NSB Subareas			
Counting post	*ns*	--	
Counting delayed	*ns*	--	
Number recognition post	*ns*	--	
Number recognition delayed	*ns*	--	
Number comparisons post	*ns*	--	
Number comparisons delayed	*ns*	--	
Nonverbal calculation post	*ns*	--	
Nonverbal calculation delayed	*ns*	--	
Story problems post	.001	.19	NS > Control***, NS > SNC**
Story problems delayed	*ns*	--	
Number combinations post	*ns*	--	
Number combinations delayed	*ns*	--	

Note: *p < .05, **p < .01, ***p < .001, NS = Number Sense Intervention, SNC = Storybook Number Competencies Intervention, NSB = Number Sense Brief, WJ-III NU = Woodcock-Johnson

General Mathematics Analyses

Table 5.6 provides *p* values and effect sizes for analyses where WJ-III NU total mathematics pretest scores were employed as dependent variable. At immediate posttest, there was a significant group effect, $F(2, 120) = 3.918$, $p = .02$, $\eta^2 = .06$. This was due to the children in the number sense group outperforming the children in the control group ($p = .05$). Analyses were conducted with Applied Problems and Calculation subtests. No group effects were found at any time point for the Applied Problems subtest. However, significant group effects were present at immediate posttest for the Calculation subtest, $F(2, 120) = 5.969$, $p = .003$, $\eta^2 = .09$.

The children in the number sense intervention outperformed both the children in the control group ($p = .01$) and children in the SNC intervention ($p = .05$).

Reading Analyses

There were no significant group effects in reading at posttest or delayed posttest.

Summary of Results

At delayed posttest, children in the SNC intervention group outperformed children in the other groups in quantitative vocabulary knowledge on both a standardized measure and a subset of a standardized measure that closely aligned with the intervention. SNC children showed an advantage in fractions and mathematics signs/symbols conceptual categories. No significant differences were found between the SNC and other groups on measures of number sense, math achievement, or reading achievement.

Table 5.6

ANCOVA Results Evaluating Intervention Effectiveness with WJ-III NU Total Math Pretest Raw Scores as Covariate

Dependent Variable	Covariate WJ-III NU Total Math Pretest		Post Hoc Tests
	p	η^2	
WJ-III NU Total Math post	.022	.06	NS > Control*
WJ-III NU Total Math delayed	*ns*	--	
WJ-III NU Subtests			
Applied Problems post	*ns*	--	
Applied Problems delayed	*ns*	--	
Calculation post	.003	.09	NS > Control**, NS > SNC*
Calculation delayed	*ns*	--	

Note: **p* < .05, ***p* < .01, ****p* < .001, NS = Number Sense Intervention, SNC = Storybook Number Competencies Intervention, WJ-III NU = Woodcock-Johnson III

Chapter 6

DISCUSSION

The overarching goal of the current study was to examine effects of a quantitative vocabulary intervention on low-income kindergartners' quantitative vocabulary and number knowledge. Children who begin school with low levels of vocabulary and/or mathematics knowledge often achieve fewer instances of academic success than their peers (Cunningham & Stanovich, 1997; Jordan et al., 2006). Previous research has suggested that storybook interventions featuring a combination of direct instruction and guided discovery learning (e.g., dialogic reading and guided play) lead to substantial gains in vocabulary understanding and literacy levels (Beck & McKeown, 2001a; Biemiller & Boote, 2006; Coyne et al., 2004; Han et al., 2010; Justice et al., 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001). Mathematics interventions featuring storybooks have also been shown to affect children's general mathematics knowledge (Hong, 1996; Jennings et al., 1992; Young-Loveridge, 2004). However, no previous studies have attempted to combine vocabulary and mathematics instruction to develop children's specific mathematics vocabulary.

To make a unique contribution to the field, the present study stepped beyond the scope of the current storybook intervention literature to build a bridge between specific mathematics conceptual vocabulary and mathematics instruction. By the end of kindergarten, the children involved in the SNC intervention demonstrated greater levels of quantitative vocabulary knowledge than their peers not involved in the intervention. As a result, the present findings are in keeping with other storybook interventions that led to gains in vocabulary knowledge (Beck & McKeown, 2001a; Biemiller & Boote, 2006; Coyne et al., 2004; Han et al., 2010; Justice et al., 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001). Although no differences were found regarding the children's number sense, unlike previous studies that sought to affect mathematics understanding through storybooks (Hong, 1996; Jennings et al., 1992; Young-Loveridge, 2004), the SNC intervention was effective in generating mathematics vocabulary growth through the use of traditional vocabulary instruction methods.

The study also suggested that there is a distinction between quantitative vocabulary knowledge and general linguistic ability. Children in the SNC intervention grew in their quantitative vocabulary knowledge more than the children in the other groups, but no group differences were found with regard to children's basic reading skills (an indicator of general language ability). Previous studies have proposed that linguistic ability may affect early numeracy (e.g., LeFevre et al., 2010; Purpura et al., 2011), but children's understanding of specific quantitative language—aside from specific number words, such as "five"—was not examined. To further explain the findings of the SNC intervention, each of the dependent variables will be discussed in detail to clarify the effects of the intervention.

SNC Intervention Effects on Quantitative Vocabulary

Children's performance on the BBCS-3:R Quantity subtest was analyzed to better understand their growth in quantitative vocabulary knowledge. Performance by group was calculated for the overall BBCS-3:R Quantity subtest as well as a subset of words that were closely aligned with the intervention and the fractions and mathematics signs/symbols conceptual categories.

The original hypothesis of the study, that significant group differences would be present at both immediate and delayed posttest on the BBCS-3:R Quantity subtest, was partially confirmed. The SNC group outperformed the other groups at delayed but not immediate posttest. It is possible that exposure to the taught words solely through the SNC intervention and not during regular classroom instruction was not enough to significantly grow children’s quantitative vocabulary knowledge since children with early numeracy difficulties have also been shown to have difficulties understanding mathematics vocabulary (Toll & Van Luit, in preparation). Although no significant group differences were present between the children in the SNC intervention group and either the number sense or control groups at posttest, the means did suggest a trend toward the children in the SNC intervention knowing more words than the children in number sense and control groups; by delayed posttest, however, the SNC intervention group outperformed the other groups. The results suggest that the SNC group’s gains in quantitative vocabulary knowledge increased over time, relative to controls.

The lack of statistical significance at immediate posttest but the presence of significant differences between the groups at delayed posttest suggests that SNC children built on the trending gains seen right after the intervention. Further analyses were conducted to provide specific information about the words that the children knew at each time point. Nevertheless, the overall goal of boosting children’s understanding of quantitative vocabulary concepts through a storybook intervention similar to Beck and McKeown's (2001a, 2001b, 2007) work was accomplished by delayed posttest.

SNC Intervention Words

To get a clearer picture of the SNC intervention group gains, analyses were run on the group of 20 words that were closely aligned to the intervention on BBCS-3:R Quantity subtest. Here, the SNC group outperformed the number sense group on both immediate and delayed posttests, but no differences were found between the SNC group and the control group at immediate posttest. As with the overall subtest, the intervention words revealed that the students in the SNC intervention did demonstrate significant improvement from pretest to delayed posttest relative to the progress of the children in the number sense or control groups.

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 *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, 85% of children across all groups did not demonstrate an understanding of "more than," and 94% did not correctly identify "less than" at pretest. 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. As such, all groups demonstrated a growth in understanding of the words by March of kindergarten.

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 at the same rate 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.

Quantitative vocabulary conceptual categories. The BBCS-3:R breaks down the Quantity subtest into different conceptual categories. These categories include relative quantity, volume, comparatives/superlatives, multiples, fractions, and mathematics signs/symbols. The conceptual categories were designed to align with the National Association for the Education of Young Children (NAEYC) standards for early mathematics (Bracken, 2006b). By examining the different categories, more information was revealed regarding the types of words and concepts that children learned over the course of the study period. Of particular interest were the reliable subareas of fractions and mathematics signs/symbols.

Fractions. At posttest, analyses revealed significant differences between the SNC group and the number sense group on the words in the fractions conceptual category (part, whole, piece, divided, half). By the end of kindergarten the SNC group significantly outperformed both the number sense group and the control group. Item analyses provided specific information about the differences between groups on individual fraction words. For instance, at pretest, 9% of children across all groups demonstrated that they understood the word “half” on the BBCS-3:R. At posttest, 30% of control group children, 23% of number sense children, and 45% of SNC group children answered the item correctly. By delayed posttest, 32% of children in the control and 31% of children in the number sense group demonstrated an understanding of “half,” as compared to 64% of children in the SNC group. Although all groups grew between pretest and posttest, only the SNC group continued a strong growth trajectory from posttest to delayed posttest. However, the 36% of SNC group children that still did not demonstrate an understanding of “half” at delayed posttest revealed, similar to the findings of the SNC Intervention Words subarea, that children with early numeracy difficulties continue struggle with mathematics vocabulary, even at the end of kindergarten.

The BBCS-3:R fractions conceptual category assesses children’s understanding of equal shares, also referred to as distributive counting (Miller, 1984), dealing (Davis & Pitkethly, 1990), or splitting (Confrey, 1995). Previous research has shown that many young children are able to learn to solve sharing problems, long before such concepts are normally taught in the classroom (Carpenter, Ansell, Franke, Fennema, & Weisbeck, 1993; Empson, 1995, 1999; Hunting & Sharpley, 1988a, 1988b). In the Carpenter et al. (1993) study, children were asked to find solutions for partitive division problems such as: "Mr. Gomez had 20 cupcakes. He put the cupcakes into 4 boxes so that there was the same number of cupcakes in each box. How many cupcakes did Mr. Gomez put in each box?" (p. 434). Similarly, the SNC intervention introduced the word "equal" by giving one possible definition as "same in number." Of the children in the study by Carpenter and colleagues, 56% were able to use a form of the strategy of separating counters into piles in order to make equal groups. As such, they demonstrated that kindergartners were able to grasp the concept of equal and unequal groupings.

In the SNC intervention, fraction concepts and vocabulary were introduced in several of the books—including *Two Greedy Bears* (Ginsburg, 1998), *Mike Mulligan and His Steam Shovel* (Burton, 1939), and *The Snowy Day* (Keats, 1962). For example, in *Two Greedy Bears* the children encountered the following vocabulary instruction about the word "half": "In the story, the bears wanted to divide the cheese into two same-size pieces—or two halves of cheese." Afterward, the children completed an activity where they circled pictures of different fruits that were divided in half. Before completing the activity, the intervention instructor discussed with the children how the fruits were like the cheese in *Two Greedy Bears* (Ginsburg, 1998): "In the story, the bears ask the fox to divide the cheese into two equal parts—or in half." The instructor asked the children to divide the fruit how the bears wanted the cheese so that each bear had an equal or same-size part. In this way, the concept of equal shares was introduced through modeling the behavior of the characters in the storybook.

Even though research indicates that children are able to understand fraction concepts beginning in preschool, such concepts are not introduced in the CCSS (CCSS Initiative, 2010) until grade 3. Fraction knowledge was also not assessed on the number sense or mathematics measures. However, the *Math Connects* (Altieri et al., 2009) curriculum does include instruction regarding part/whole and equal/unequal parts in the last weeks of the school year. Although fractional concepts were not introduced in the children's regular mathematics curriculum until the end of kindergarten, the statistically significant performance of the SNC children on this section of the BBCS-3:R Quantity subtest suggests that children with early numeracy difficulties can learn and understand fraction words. A remaining challenge is how to connect children's understanding of fraction concepts to more general numerical reasoning.

Mathematics signs/symbols. The present study also suggested that it might be helpful to introduce addition and subtraction concepts earlier in kindergarten. Similarly, Jordan and colleagues (Dyson et al., 2013; Jordan et al., 2012) have demonstrated that children from low-income backgrounds can learn to develop addition and subtraction competencies above and beyond what is taught in the standard kindergarten curriculum. At posttest and delayed posttest, the SNC intervention group outperformed both the number sense group and the control group on concepts from the mathematics signs/symbols conceptual category (+/–).This is not surprising since *Math Connects* (Altieri et al., 2009) does not introduce the concepts of addition and subtraction—

including the "+" and "–" signs—until the last few weeks of kindergarten. For instance, at pretest, 1% of children across all groups demonstrated that they understood the relationship between the word "subtract" and the "–" symbol on the BBCS-3:R. At posttest, 5% of control group children, 2% of number sense children, and 24% of SNC group children demonstrated that they understood the concept. By delayed posttest, 5% of children in the control and 7% of children in the number sense group answered the item correctly, while 29% of children in the SNC group selected the correct response. Although the SNC group children grew the most between pretest and posttest, the 71% of SNC group children that still did not demonstrate an understanding of the relationship between "subtract" and "–" at delayed posttest demonstrated, similar to the findings of the SNC Intervention Words and fractions subareas, that children with early numeracy difficulties continue struggle with mathematics vocabulary, even at the end of kindergarten.

In the SNC intervention, mathematics signs/symbols were introduced in a number of the books—including *McElligot's Pool* (Seuss, 1947), *Olivia* (Falconer, 2000), *Mike Mulligan and His Steam Shovel* (Burton, 1939), and *The Snowy Day* (Keats, 1962). For example, children were first introduced to the concept of "add" in *McElligot's Pool*: "In the story, the Dog fish scared the other fish when he swam toward them. If we add the fish together, we can find out how many fish were scared by the Dog fish. Add means combine together to make a larger amount. This is the sign for add: '+.'" Children were encouraged to connect the different representations of "add," including the vocabulary word and the mathematical sign. After learning the word, the children completed an activity using cards with pictures of fish to tell stories about addition. For example, the instructor explained that two fish plus one fish equals three fish. Through the direct vocabulary instruction and the activity, the children learned to connect the word “add,” the symbol “+,” and the action of combining together two numbers to make a larger amount.

Similarly, in *Olivia* (Falconer, 2000), the SNC intervention first presented the concept of subtraction: “In the story, Olivia and her mom argue about the number of books to read. Olivia’s mom subtracts from the number of books that Olivia wants to read. That means that she takes away from the number of books that Olivia wanted. This is the sign for subtract: ‘–.’” Later in the lesson, the children completed an activity using the add/subtract sign cards. The children took turns telling stories using addition and subtraction. For example, students added and subtracted books to demonstrate how Olivia and her mother argued over how many books to read before bed. Again, the children learned to connect the mathematical signs/symbols with the words “add” and “subtract” and the actions of combining together and taking away.

SNC Intervention Effects on Early Mathematics

Previous mathematics storybook interventions (e.g., Hong, 1996; Jennings et al., 1992; Young-Loveridge, 2004) generated statistically significant gains in children’s early numeracy knowledge. Therefore, the original hypothesis regarding number knowledge purported that the children in SNC intervention would outperform the control group on measures of number sense and general mathematics achievement. However, after analyzing the results of the NSB total score, no significant differences were found between any of the groups at immediate posttest or delayed posttest. Similarly, on the WJ-III NU total mathematics measure, the SNC group did not outperform either of the other groups at immediate or delayed posttest. To understand where the differences occurred between groups, separate analyses were conducted using the WJ-III NU Applied Problems and Calculation subtests. No between-group differences were found at any time point for the Applied Problems subtest. The SNC group also did not outperform either of the other two groups on the Calculation subtest at immediate posttest, and no significant differences were found between any of the groups at delayed posttest.

In order to uncover a potential cause for the lack of differences between the groups, an analysis was conducted of the *Math Connects* (Altieri et al., 2009) curriculum, which was used by all participating elementary schools. Many of the 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* before and 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. As a result, all children in the study were exposed to many of the concepts taught in the SNC and number sense interventions.

Additionally, only one of the previous mathematics storybook interventions (Young-Loveridge, 2004) was conducted with children demonstrating early numeracy difficulties, but the study focused on skills like understanding the count sequence and did not include more advanced concepts such as addition and subtraction. 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 Applied Problems subtest. This may have led to floor effects, which negated the ability of the test to show effects of the interventions. The combination of improved classroom mathematics instruction and the focus on children with low initial levels of numeracy knowledge may have led to the lack of significant differences between the groups on mathematics measures.

SNC Intervention Effects on Reading Achievement

No significant differences were found between SNC and the other groups on the WJ-III NU total reading score at posttest or delayed posttest. It was not hypothesized that the quantitative vocabulary intervention would have effects on children's ability to recognize letters and words or comprehend information presented through pictures or words. The SNC intervention did not devote any time to building children's basic reading skills—beyond the development of new vocabulary knowledge. Additionally, Toll and Van Luit (in preparation) found that although early numeracy difficulties often co-occur with mathematics language difficulties, general language problems do not necessarily go hand-in-hand with numeracy difficulties.

Teaching Observations

To gain a more detailed understanding of how the SNC intervention was carried out in the individual groups, the researcher collected teaching observations during the weekly group meetings attended by all intervention instructors. The observations provided a window into the inner workings of the individual intervention groups. During the course of the intervention, the instructors experienced firsthand the difficulties inherent within effectively teaching an instructional intervention to small groups of kindergarten students. In particular, behavior issues seemed to be a struggle in many of the intervention groups and may have compromised the effectiveness of the intervention. Along with behavior issues, instructors also faced instructional issues that were discussed during the weekly meetings with input from the researcher.

The group meetings began with the researcher asking the instructors to talk about any behavioral issues that arose during the previous week's instruction sessions. Normally, at the end of each intervention session, children received a sticker and a Positive Behavior Support (PBS) coupon recognizing their on-task behavior and positive attitude. The school district in which the intervention took place featured an extensive PBS program in which behaviors that highlighted students' honesty, respectfulness, and responsibility were rewarded with coupons. These coupons could then be exchanged for special assemblies, pizza parties, and items in the school store. To encourage a sense of continuity of behavioral expectations throughout the school day, the SNC instructors received PBS coupons from the classroom teachers to distribute to the children for positive behaviors.

When children were disruptive or had trouble staying on task during group sessions, the instructors discussed with the classroom teacher behavioral strategies that worked in the regular classroom setting. For example, after discussing with the classroom teacher about the behavior of two particular children, the researcher implemented the stoplight management behavior system in an intervention group comprised of children from that teacher's classroom. Each day, when the researcher went to collect the children from the classroom, the teacher informed the researcher about the children's behavior status for the day up until that point (i.e., green for good behavior, yellow for exhibiting at least one off-task behavior, and red for serious infractions). The researcher would remind the children of their status during the group to encourage on-task behaviors. In addition, instructors stressed to the students that receiving stickers and PBS coupons was based on their behavior during the lesson. Implementing the same behavior system used in the classroom provided the children with a sense of continuity throughout their school day and encouraged a productive learning environment in the intervention groups.

The instructors also discussed the instructional aspects of the lessons during the weekly group meetings. Every meeting, the instructors reviewed the upcoming week's lessons and practiced administering the activities in pairs. The researcher also asked the instructors to share what activities worked and did not work to instruct the various vocabulary words and mathematical concepts. To accomplish this, the instructors went around the room and explained how each activity from the past week played out in their groups. Activities that particularly engaged children's attention were often modified and extended to be included in future lessons. For example, activities involving manipulatives, such as Monkeys in a Barrel, gave all children the opportunity to connect their intuitive understandings of mathematical concepts to concrete representations (Clements, 1999). Previous research has demonstrated that, when combined with guidance from an instructor, the use of manipulatives helps children engage with mathematical ideas by creating integrated concrete knowledge (Clements, 1999). Integrated concrete knowledge is generated when children view manipulatives as only one part of a larger mathematics conceptual structure (Clements, 1999). The SNC intervention encouraged the development of this type of knowledge by highlighting explicit connections between mathematical representations in the vocabulary instruction and mathematics activities.

Instructors also shared what concepts and words were particularly difficult for the children to understand. Since many of the intervention words were featured in more than one storybook, the researcher was able to feature activities in future lessons that continued to focus on topics that the instructors determined were particularly challenging. For instance, the word “add” was presented in *McElligot’s Pool* (Dr. Seuss, 1947), *Olivia* (Falconer, 2000), and *The Snowy Day* (Keats, 1962). In *McElligot’s Pool*, the children used manipulatives shaped like fish to practice adding. After receiving very positive feedback about children’s engagement in this activity, the researcher included similar activities using objects from the story, such as snowflakes in *The Snowy Day*, to practice adding.

Each week, the instructors also discussed the children who had the most difficulty during the intervention sessions. These children ranged from having very low levels of English understanding to issues understanding specific lesson content. The researcher and instructors brainstormed ways to reach the individual children in each group by highlighting the children’s strengths, taking time to reinforce particularly challenging concepts, and assessing other factors that might be affecting children’s performance. Sometimes, the group discussion revealed a situation that could be altered to improve a group’s outcomes. For example, a group in one particular school was located in the hallway and was constantly distracted by children going to recess. As a result of the weekly meetings, the researcher arranged for this group to move to a new location, and the instructor reported that, as a result, the children were more engaged in the lessons and behavior issues improved.

Finally, the instructors shared valuable anecdotal information about their experiences during the group meetings. For instance, instructors detailed how the children would relate the stories to their own lives, such as with the book *The Snowy Day* (Keats, 1962). The students enjoyed talking about times that their own socks were wet from the snow, like the main character in the story, and the different activities that they like to do outside on snowy days. The instructors also continually highlighted the success of guided play activities in getting children to engage with the vocabulary words and concepts. Children particularly enjoyed drawing pictures of their "straight," "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. (See figure 6.1 for a sample drawing.) They each drew their routes to school and explained their drawings to the others in the group. Instructors also shared that they learned a great deal about how difficult it can be to teach struggling learners during the course of the SNC intervention, and they strongly felt that the intervention helped further prepare them for their careers as future teachers.

The teaching observations revealed the strengths and limitations of the SNC intervention by highlighting the inner workings of individual intervention groups. At the weekly group meetings, instructors consistently raised the issue of behavior problems

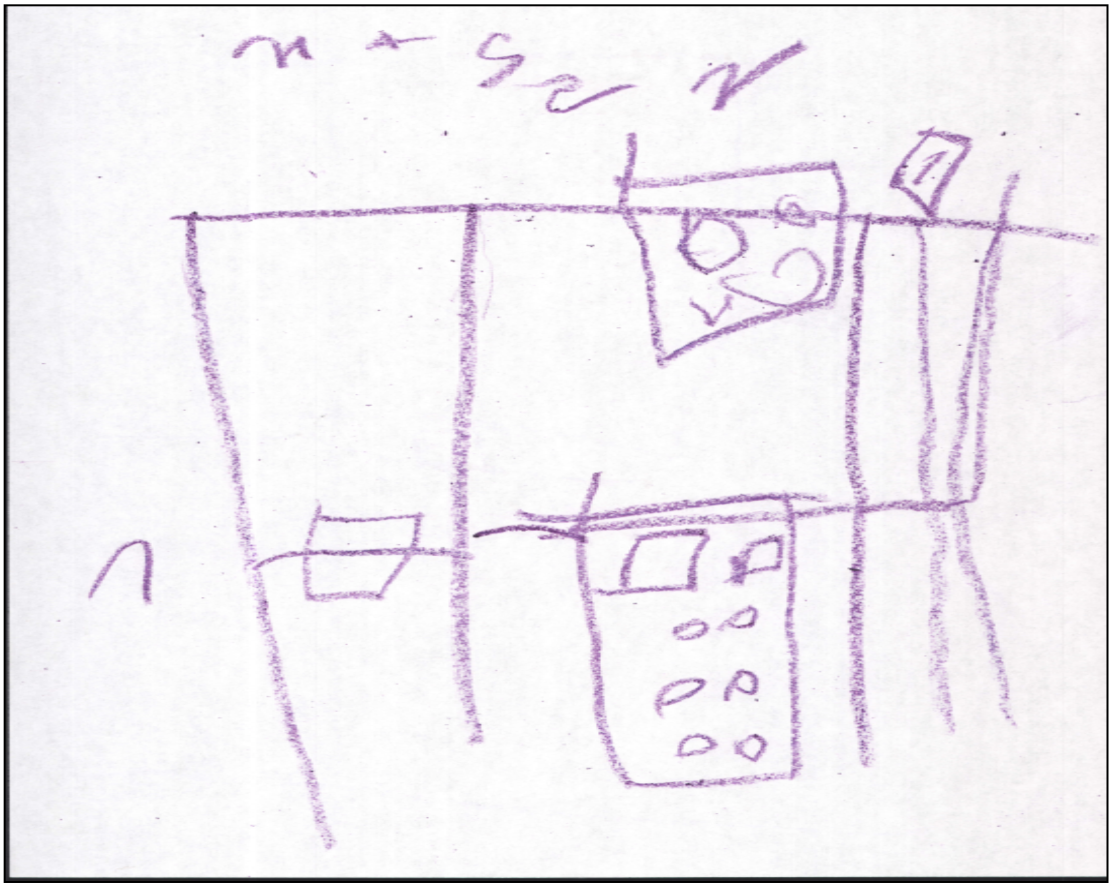

Figure 6.1. Product of activity during *Harold and the Purple Crayon* (Johnson, 1955)

interfering with the effectiveness of the SNC intervention, particularly due to the 30-minute length of each session. As a result, any future versions of the intervention will take this criticism into consideration. Additionally, the instructors' feedback about successful activities helped to improve the quality of the activities in future lessons. By incorporating activities that children enjoyed and engaged with, the instructors helped the researcher target the intervention for a population of students with early numeracy difficulties. The teaching observations provided valuable feedback regarding how to refine the intervention as it occurred and how to improve it for future use.

Implications for Instruction

Pre-teaching is an educational strategy that features instruction of key words and concepts before they are introduced in the general classroom curriculum (Munk, Gibb, & Caldarella, 2010). By briefly introducing concepts during pre-teaching, students get an opportunity to create a foundation of basic understanding on which to build more advanced knowledge and access the general curriculum (Burns, Dean, & Foley, 2004; Munk et al., 2010).

Both the fractions and mathematics signs/symbols conceptual categories featured concepts that were not taught in the *Math Connects* (Altieri et al., 2009) curriculum until after the intervention ended, according to school district curriculum pacing guidelines and teacher report. Fraction words and mathematics signs/symbols were not addressed at any point in the *Journeys* (Baumann et al., 2011) language arts curriculum. As such, it is likely that the early introduction of both fraction concepts and mathematics signs/symbols helped the children understand the later classroom instruction of these topics.

Previous research has demonstrated that pre-teaching both mathematics and readings concepts increases children's understanding in these areas (Beck, Perfetti, & McKeown, 1982; Lalley & Miller, 2006; Wixson, 1986). Lalley and Miller (2006) exposed small groups (n = 4) of third graders to the concepts from their mathematics curriculum one to three days prior to the content's introduction to the whole class. The children in the pre-teaching groups experienced significantly improved mathematics outcomes (Hoover et al., 2001) as compared to their peers who did not receive pre-teaching including concepts, problem solving, and computation.

In the area of reading instruction, both Beck and colleagues (1982) and Wixson (1986) examined the effects of pre-teaching on vocabulary knowledge. The children that learned vocabulary words during initial pre-teaching sessions were better able to understand and apply the words in novel context than their classmates who did not receive pre-teaching. In a study of fifth-grade students, Wixson (1986) established that children who participated in pre-teaching of vocabulary words were better able to comprehend the elements of the story that related to the instructed vocabulary than children who did not participate in pre-teaching.

Although these studies took place in upper elementary school classrooms, the SNC intervention suggests that pre-teaching certain quantitative vocabulary words assists kindergarten students' understanding of those quantitative words. By the end of the intervention, only the SNC group had received instruction regarding fraction concepts. For example, during instruction on the book *Two Greedy Bears* (Ginsburg, 1998), children learned about "half" by identifying and creating same-sized or equal parts, like the characters in the story.

After receiving both the SNC intervention and regular classroom fraction concepts instruction, the children in the SNC group outperformed both the number sense and control-group children on the BBCS-3:R fractions conceptual category. The children in the SNC group were given an initial opportunity to explore fraction concepts that was then reinforced by general classroom instruction in the same concepts. This dual exposure gave them the experience necessary to develop a clearer understanding of fraction words than their peers who were only exposed to the concepts once.

Additionally, pre-teaching effects were also evident for the BBCS-3:R mathematics signs/symbols conceptual category. One potential reason for the narrowing of the gap between the number sense and SNC groups is that the number sense group also received instruction regarding addition and subtraction during their intervention. However, the children in the control group did not receive advanced instruction regarding mathematics signs/symbols before their introduction in the *Math Connects* (Altieri et al., 2009) curriculum after the conclusion of the interventions. For example, *Math Connects* introduces subtraction by explaining the action and the associated symbol (Altieri et al., 2009). As such, the children in the SNC and number sense groups both experienced greater levels of success than the control group on the mathematics signs/symbols conceptual category, potentially due to their multiple exposures to addition and subtraction concepts.

No previous studies have examined the effects of pre-teaching these specific quantitative concepts at such long (~ 8–16 weeks) duration between initial introduction and their debut in the regular classroom curriculum. However, the data regarding fraction concepts and mathematics signs/symbols from the BBCS-3:R Quantity subtest suggest that pre-teaching may have improved the ability of kindergarten students with demonstrated low mathematics achievement to grasp these quantitative vocabulary words. Since fractions concepts in particular are not present in the CCSS (CCSS Initiative, 2010) until grade 3, the finding that children with mathematics difficulties can understand and identify these concepts as early as kindergarten provides promising support for the ability of these children to catch up to their peers in the area of basic fraction concepts.

The success of pre-teaching strategies also highlights the unique instructional needs of children who enter kindergarten with low levels of mathematics understanding. Previous studies by Jordan and colleagues (Dyson et al., 2013; Jordan et al., 2012) have demonstrated that children at high risk for mathematics failure can catch up to their peers by taking part in a supplemental targeted number sense intervention. Similarly, the SNC intervention showed that children with low initial levels of mathematics understanding need multiple exposures to concepts to solidify their understanding. By introducing quantitative vocabulary words before they appeared in the classroom mathematics curriculum, the SNC intervention was tailored to the specific needs of low-performing students.

Limitations of the Study

There are several limitations of the present study. One concern was the lack of a systematic measure of students' engagement in the intervention. Research has found that students' engagement, defined as the psychological input and effort put forth in order to understand academic concepts, in mathematics is key to achieving growth for children who start kindergarten with low levels of mathematics knowledge (Bodovski & Farkas, 2007). Using data from the Early Childhood Longitudinal Study-Kindergarten Cohort, Bodovski and Farkas found that low-achieving kindergartners who were highly engaged demonstrated a high rate of growth in mathematics achievement, of which 50% of the variance was accounted for by student engagement. As such, classroom behavior observations and teacher reports about student performance might have added additional information about the performance of the children in the SNC intervention.

The use of a measure such as the *Behavioral Observation of Students in Schools* [BOSS] (Shapiro, 2010) may have provided a reliable way to measure student engagement. The BOSS is used to assess children at risk for academic failure as well as analyze the effectiveness of educational interventions (Fredricks et al., 2011). Research has shown that it is important to examine the different levels and growth trajectories of children's performance in various academic skills (Ritchey & Speece, 2004). As a result, it is important to consider children's academic growth over time in their social and behavioral contexts.

Additionally, the relatively short duration of the intervention (eight weeks) may have limited the ability of the children to demonstrate gains from instruction and sustain the gains that they did achieve. Since all of the children had early numeracy difficulties, they may have benefitted from additional instructional time to review the mathematical concepts presented in the intervention. Other interventions for children with numeracy difficulties (e.g., Bryant et al., 2011; Fuchs et al., 2005; Fuchs et al., 2012) featured intervention lengths of 16–19 weeks.

The successful intervention studies by Fuchs and colleagues (2005, 2012) featured one-on-one instruction, which may have also benefitted the children in the SNC intervention. 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 receive immediate and tailored feedback from the instructor. The limited time span of the intervention also meant the time spent addressing any behavioral issues that the children demonstrated during instruction could not be made up in additional sessions. Since the interventions took place in small groups of four students, children occasionally behaved such that they needed to return to class in the middle of a session or needed to be redirected to the task at hand, which briefly interrupted instruction. By providing additional instruction time, the inclusion of additional intervention sessions may have increased the ability of children in the SNC intervention to demonstrate clear quantitative vocabulary and number sense gains above and beyond those made by the children in the other groups.

Future Research

In the current study, quantitative vocabulary instruction was directed primarily at improving children's quantitative vocabulary knowledge, with a secondary emphasis on number sense. Future research might include more directed mathematics instruction within a quantitative vocabulary intervention to potentially generate gains in number sense as well as quantitative vocabulary knowledge. Since the current intervention was most successful in introducing mathematical signs/symbols content, future research should focus on helping children develop mathematical knowledge that will help them better understand their regular classroom instruction.

A significant number of studies have examined either reading or mathematics interventions; however, very few studies have looked at both pre-reading skills, including vocabulary knowledge, and mathematics simultaneously. Therefore, future research should explore additional ways to combine the two areas of instruction. By combining mathematics instruction with storybook reading and vocabulary introduction, children learn that mathematics does not just belong within the confines of math class. On the contrary, they learn that mathematics is found throughout everyday life—even within the pages of their favorite storybooks.

Future research should also consider using an author-generated vocabulary measure alongside a standardized vocabulary measure. Research has shown that researcher-authored measures are more likely to register student vocabulary gains than are standardized tests (National Reading Panel, 2000). For the current study, the SNC Intervention Words subset of the BBCS-3:R Quantity subtest was used as a specific measure of the concepts taught in the SNC intervention, and this subset of the larger measure did register gains for the SNC intervention group. However, future studies may elect to include their own measure alongside a standardized measure such as the BBCS-3:R to provide even more data about children's vocabulary knowledge. Author-generated measures are able to focus on children's understanding of the words in the way they were taught by presenting words in familiar contexts from the storybooks.

Future examinations of the SNC or similar interventions should also include both qualitative and quantitative research methods. The addition of systematic qualitative analyses of student engagement will allow researchers to understand how the intervention actually generates vocabulary and mathematics growth. Previous research has shown that classroom attention problems—a key indicator of engagement—mediates the relationship between children's number sense in kindergarten and mathematics outcomes in first grade as well as the relationship between kindergarten reading skills and first-grade reading outcomes (Jordan, Hassinger-Das, Glutting, Irwin, & Dyson, in preparation). To gauge the effects of engagement, researchers could conduct observations of intervention groups and describe in detail children's interactions with the instructor and the materials used in the intervention. Descriptions of the interactions that take place within individual small groups will provide a more nuanced understanding of the ways in which student engagement and other factors affect children's ability to be helped by the intervention.

Future iterations of the SNC intervention may be explored as home-based or supplemental add-ons to the traditional classroom instruction in both vocabulary and mathematics. Teachers in schools serving children from low-income backgrounds often face particular challenges due to a lack of resources. Additionally, children at high risk for academic difficulties in both reading and mathematics need specific, targeted instruction in both areas (Beck & McKeown, 2001a; Dyson et al., 2013). By combining mathematics and vocabulary learning into one home-based or supplemental instructional intervention, future studies of interventions similar to SNC will address two crucial subjects at the same time while building on knowledge children will also be exposed to in the regular classroom (Gary & Whitin, 1994).

However, if the SNC or similar intervention is to be used as a supplement to classroom instruction, it must be accessible for teachers and paraprofessionals. As such, future research should explore how to modify the intervention for use in the classroom. Ramani, Siegler, and Hitti (2012) successfully transitioned the Great Race Game from a research to a classroom setting. The authors observed paraprofessionals leading small groups of three children in the playing of the Great Race Game. They noted that having paraprofessionals facilitate the groups led to numerical knowledge gains for the children in the intervention. For the SNC intervention, future research should take a successful version of the intervention and adapt it for use by classroom teachers or paraprofessionals.

From a developmental perspective, future research should also address how the relationship between mathematics vocabulary and general mathematics knowledge differs for high- and low-achieving students. If children with early numeracy difficulties also have issues understanding mathematics vocabulary, interventions targeting these students should also include a specific focus on mathematics vocabulary alongside other mathematical concepts.

Implications for Practice

There is a persistent gap between low- and middle-income children with regard to both their vocabulary knowledge and mathematics abilities (Hart & Risley, 1995; Jordan et al., 1994; Jordan et al., 2006). Children from middle-income backgrounds are often introduced to greater numbers of vocabulary words and exposed to more mathematical situations before entering kindergarten than their low-income peers, and as a result, children from low-income backgrounds have fewer chances to achieve academic success throughout their school careers (Cunningham & Stanovich, 1997). However, research suggests that it is possible for most children—regardless of their SES backgrounds—to develop number and language competencies through direct assistance (Beck & McKeown, 2001a; Dyson et al., 2013; Han et al., 2010; Jordan et al., 2012). The present study demonstrated that a quantitative vocabulary intervention combining vocabulary and mathematics concepts helped children from low-income families boost their quantitative vocabulary comprehension above and beyond their peers not involved in the SNC intervention. By implementing a combination vocabulary and mathematics intervention in addition to regular classroom instruction, educators may address critical pre-reading and mathematics skill areas at the same time.

In recent years, education in the United States has become increasingly standards-based. In particular, the introduction of the CCSS (CCSS Initiative, 2010) has answered the call for a framework that outlines the optimal educational trajectory for all students. The CCSS are designed to provide an educational framework for grades K–12 to prepare students for college and the workforce. The CCSS Initiative is led by the states and coordinated by the National Governors Association Center for Best Practices and the Council of Chief State School Officers. Education and content-area scholars, teachers, and school administrators developed the CCSS collaboratively while also including successful standards and requirements from the curricula of other countries. The state in which the intervention took place formally adopted the CCSS beginning in the 2011–2012 academic year.

To be successful in the climate of standards-based education, interventions such as the SNC intervention must align with the CCSS and other relevant educational frameworks. By including crucial grade-level benchmarks that were also required in classroom instruction, the SNC intervention ensured that children were exposed to the most important mathematics and vocabulary concepts that will help them succeed in kindergarten and beyond.

The study also has implications for teaching practices, although further inquiry is needed in this area. The findings regarding the successes of children in the SNC intervention on the BBCS-3:R Quantity subtest and the fractions and mathematics signs/symbols conceptual categories suggest that mathematics vocabulary may be effectively instructed through a storybook intervention. As such, this quantitative vocabulary intervention joins general vocabulary interventions that featured a combination of direct instruction and guided discovery learning techniques. Since the intervention demonstrated that it was possible to instruct mathematics vocabulary through storybook reading, teachers and parents/caregivers can also integrate mathematics vocabulary into any instance of shared book reading. Even in informal settings, educators and parents/caregivers can discuss the mathematical concepts that arise in storybooks and connect the stories with related number activities. In these ways, the lessons from the SNC intervention may be incorporated outside the structure of the formal intervention and into children's everyday experiences with storybooks.

Summary and Conclusions

The present study addressed a topic that has significant implications for educational practice. In particular, it sought to uncover the effects of a quantitative vocabulary intervention on children's quantitative vocabulary knowledge and number sense. The children in the SNC intervention performed significantly better on a measure of quantitative vocabulary at the end of kindergarten than their peers who did not receive the intervention. Children in the SNC intervention made notable gains in the conceptual categories of fractions and mathematics signs/symbols. The main implication of the findings is that a quantitative vocabulary intervention improved children's quantitative vocabulary knowledge, although it did not have a significant impact on number sense development as measured in this study.

The present study is timely with respect to the focus of education in the United States becoming increasingly standards-based, including the introduction of the CCSS (CCSS Initiative, 2010). The study addressed a novel way for combining vocabulary and mathematics instruction in a manner that supports learning while still working within a standards-based educational framework. This type of instruction is designed to help all students, regardless of their SES backgrounds, achieve academic success and become productive members of society.

Continued research in this area will open the door for exploration of deeper connections between vocabulary and mathematics concepts that may improve students' academic outcomes. The present study highlighted the difficulties that arose when instructing children with early numeracy difficulties, such as the need for extra instructional time beyond the 30 minutes allotted for the intervention. The children in the SNC intervention did grow in their number sense knowledge, but at similar rates to children in the other two groups. Since the use of the *Math Connects* (Altieri et al., 2009) curriculum spurred number sense gains for all groups in the present study, future research will explore the effects of the SNC intervention in schools with different types of classroom mathematics curricula. Future iterations of the SNC intervention will also include more targeted mathematics instruction in areas including comparatives/superlatives and relative quantity, which were not as effective as fractions and mathematics signs/symbols in the present intervention.

Additionally, the gains that the SNC group children made in quantitative vocabulary knowledge demonstrated that children with early numeracy difficulties benefit from additional instruction in mathematics vocabulary that goes beyond their regular classroom mathematics instruction. For the SNC intervention to reach the greatest number of children with early numeracy difficulties, the intervention must be accessible for educators, paraprofessionals, and parents. Future studies will examine how to transition the intervention from employing graduate and undergraduate students as instructors to asking classroom teachers, paraprofessionals, and parents/caregivers to carry out the supplemental intervention.

Finally, future research will examine how the relationship between quantitative vocabulary and general mathematics knowledge differs for high-achieving students and students with early numeracy difficulties. If quantitative vocabulary uniquely predicts general mathematics knowledge differently for children with varying levels of initial kindergarten numeracy understanding, such findings will call for the inclusion of quantitative vocabulary instruction in future instructional interventions designed to supplement classroom mathematics instruction for children with early numeracy difficulties. By gaining a better understanding of the relationship between mathematics vocabulary and general mathematics knowledge for children with early numeracy difficulties, researchers and educators will be able to provide targeted and effective numeracy instruction to support children's future academic successes.

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Appendix A

SAMPLE INTERVENTION LESSON

McELLIGOT'S POOL
SESSION ONE

OBJECTIVE

Students will be able to identify and understand the following quantitative vocabulary words in the context of the story as well as in other contexts: with/without, same, short/long, bigger/smaller, add. Students will also create connections between the story and the following number sense concept(s): counting, number relations, and number operations.

VOCABULARY

Session One
- With/Without
- Same
- Short/Long

Session Two
- Bigger/Smaller
- Add

❖ **INTRODUCTION**

- Say, **Let's go over how we act in our group. When we get together, I expect you all to listen carefully and do your best. OK?** (Wait for a response.) **When I'm talking, what should you be doing?** (Listening.) **That's right! And when I call on one of you to speak, we will all listen to you. That is how we show respect for each other. It's important that we respect each other so we can all do our best.**

- ❖ **READING THE STORY**

  - ➢ ***McElligot's Pool* (Dr. Seuss)**
    Say, **Today we are going to read a book called *McElligot's Pool*. What is happening on the cover of the book?** (Students may say that someone is trying to catch a fish.) **Good! I wonder if the fish will bite. Let's find out together!** (Read through the story while pointing out interesting pictures and/or highlighting the comments of the students.)

    Completed ____ NOTES:

  - ➢ **Vocabulary**
    Skim through the story a second time to highlight the vocabulary words. Say, **Now we are going to go over some math words from our story.**

    - *With/Without:* **When the farmer said that the boy could sit for fifty years with his worms and his wishes, he meant that the boy had those things while he sat on the bank of the pool. Without, or not having, the worms, the boy would not get the fish to bite his hook.**

    - *Same:* **There are the same number of cans and bottles on the bottom of McElligot's Pool. Same means that two groups are exactly alike.**

    - *Short/Long:* **The short fish is smaller in length than the long fish. You can put together many short fish to make the length of the long fish**.

Completed ____ NOTES:

- ❖ **INSTRUCTION-—Vocabulary Introduction**

  - **With/Without**
    - ❖ **We are going to learn how to use some words from *McElligot's Pool*. In the story, the farmer tells the boy that even if he sat for fifty years with his worms, he would not catch a fish in the pool. In a pool with fish, having worms would help the boy catch one. However, the farmer said that even having lots of worms would not catch fish in McElligot's Pool, because no fish live there. McElligot's Pool is a pool without fish, because it does not have any. Let's say the words "with" and "without" together.**

- ❖ **Let's think of some other examples of "with" and "without." Raise your hand to answer my questions. Then we will say the words together.**
  - **Would fishing with or without a flashlight be the best idea? Tell me why.** (Child could provide rationale for either.)
  - **Would you want to be with or without a long curly nose? Tell me why.**
  - **I would like everyone to tell me one thing that they do not like to be without during the school day.** (Go around and have each child answer.)
- ❖ **What are the words that mean to have or not have something?**

- **Short/Long**
  - ❖ **We are going to learn how to use some words from *McElligot's Pool*. In the story, the boy says that he might catch a short or a long fish. The short fish does not have as much length as the long fish. If you put several short fish next to each other end to end, you could make them the same length as the bigger long fish. Let's say the words "short" and "long" together.**
  - ❖ **First, I am going to name some animals from our story, and I would like you to raise your hand and name a longer animal.** (Show the pages in the book with each animal.)
    - **Whale**
    - **Seahorse**
    - **Stout fish**
  - ❖ **Now, I am going to name some objects from our story, and I would like you to raise your hand and name a shorter object.**
    - **Old shoe**
    - **Submarine**
    - **Fishing pole**
  - ❖ **What word describes the fish that is small in length? Which word describes the fish with the bigger length?**

- **Same**
  - ❖ **In the story, there are the same number of cans and bottles on the bottom of McElligot's Pool. "Same" means that the groups of cans and bottles are exactly alike in number. Let's say the word "same" together.**
  - ❖ **Let's think of some other examples of things that are the same in number.**
    - **The number of fish on pg. 5 vs. pg. 6**
    - **The number of fish on pg. 9 vs. pg. 10**
    - **The number of fish on pg. 15 vs. pg. 16**

- ❖ **What is the word that means "exactly alike"?**

Completed ____ NOTES:

- ❖ **INSTRUCTION—Direct Mathematics Instruction (SHORT/LONG)**

  - o Use the measuring activity. Say, **Now we are going to do another activity. These fishermen, like the boy in our story, are trying to figure out how long these objects are. They are using the fish to figure it out. Look at the pictures and count how many fish lengths make up each object. Then, write that number on the line. We'll go over your answers together after you are finished.**

  Completed ____ NOTES:

- ❖ **WORD-BASED ACTIVITY**
  - o **SAME**
    - ❖ Use the Monkeys in a Barrel. Give two children at a time piles of monkeys. Ask, **Do ___ and ____ have the same number of monkeys? How do you know?** (Repeat so all children play twice.)
  - o **WITH/WITHOUT**
    - ❖ Use the ice cream cards and have the children separate the cones into ones with or without toppings or other attributes.
      - Say, **I am going to put these ice cream cards out on the table. I would like the group to separate the cards into cones with and without toppings.** (Have children separate the cards by a second attribute after they have finished the first task.)

- ❖ ***SNAKES & LADDERS*** **(Refer to Master List of Questions)**

  - o Say, **Because you all worked so hard this week while we learned about *McElligot's Pool*, I am going to give you each a sticker.** (Hand out lesson stickers.)

  Completed ____ NOTES:

SESSION TWO

- ❖ **INTRODUCTION**

  - o Say, **Let's review how we should act when we are together. When we get together, I expect you all to listen carefully and do your best. OK?** (Wait for a response.) **When I'm talking, what should you be doing?** (Listening.) **That's right! And when I call on one of you to speak, we will all listen to you. That is how we show respect for each other. It's important that we respect each other so we can all do our best.**

- ❖ **READING THE STORY**
  - o Read through the book again while pointing out interesting pictures and/or highlighting the comments of the students, and when you get to a vocabulary word, complete the following:
    - ❖ Say, **Who remembers what "long" means?**

  - o **Vocabulary—**Skim through the story a second time to highlight the vocabulary words. Say, **Now we are going to go over some math words.**

    - o *Bigger/Smaller:* **"Bigger" means a group with more fish than the smaller group. The bigger group is also larger in size than the smaller group. The smaller group has fewer fish than the bigger group.**

    - o *Add:* **The Dog fish scared the other fish. How many fish did he scare? If we add them, we can find out. "Add" means "combine together to make a larger amount."**

- ❖ **INSTRUCTION—Vocabulary Introduction**
  - o **Bigger/Smaller**
    - ❖ **In the story, the boy describes all kinds of fish. Some fish are big, and some fish are small. If one fish is larger than another fish, for example, the whale versus the fish with the long curly nose, you can say that it is bigger. If a fish is not as large as another fish, for example, the short fish and the fish with the long flowing whiskers, you can say that it is smaller. Also, when you look at the groups of fish, the group with more fish is the bigger group and the group with fewer fish is the smaller group. Let's say the words "bigger" and "smaller" together.**
    - ❖ **Let's think of some other examples of the words "bigger" and "smaller." I will say two things, and I would like you to raise your hand if you can tell me which group is bigger and which group is smaller.**

- A group of two fish and a group of seven fish
  - **A group of five kids fishing and a group of ten kids fishing**
  - **A basket of ten worms and a basket of eight worms**
- ❖ **What is the word that describes the larger fish or the group with more fish in the story? What word describes the little fish or the group with fewer fish?**

- o **Add**
  - ❖ **In the story, the Dog fish scared the other fish when he swam toward them. If we add the fish together, we can find out how many fish were scared by the Dog fish. "Add" means combine together to make a larger amount.**
  - ❖ **Let's look through our story and see what we can add.**
    - **How many fish are looking at the boy's fish hook?**
    - **How many fish from the Tropics are swimming to McElligot's Pool?**
    - **What else could we add? What do you see? (**Have the students provide examples from the story.)
  - ❖ **What is the word that means "combine together to make a larger amount"?**

Completed ____ NOTES:

❖ **INSTRUCTION—Direct Mathematics Instruction (BIGGER/SMALLER, ADD)**

- o Use the Numbers 0–25 Flashcards. Say**, Now we are going to compare big and small groups. Here are two groups. Raise your hand to tell me which is the bigger group and which is the smaller group. Count the number of objects to find out the answer.** (Make the following groups using the picture sides of different cards: **5 vs. 3, 7 vs. 4, 10 vs. 8, 6 vs. 9**.)

- o **ADD**
  - ❖ Next, use the Fish cards to reinforce the concept of "add."
    - **Let's practicing adding with our Fish cards.** (Give one child five Fish cards.)
    - **Ask two children to tell a story by adding the fish. Give an example first: I will put down two fish. Now, you put down one more fish. Let's add the fish to figure out how many we have. 2 + 1 = 3. Let's see how we can write it. 2 plus 1 equals 3. Remember, "equal" means "same as." So, 2 plus 1 is the same as 3.** (Give all children a turn.)

Completed ____ NOTES:

- **WORD-BASED ACTIVITY**

    - Use the Transportation Station worksheet. Say, **If we wanted to get across McElligot's Pool, how could we do it?** (We could use a boat.) **Now we are going to follow directions to find bigger and smaller examples of ways to get where we want to go.**
    - Say, **Look at the first picture. Which car is bigger? Draw a rectangle around the bigger car. Do the same thing for the next two pictures.**
    - Say, **Look at the first picture in the bottom row. Which picture is smaller? Do the same thing for the next two pictures. What is the last picture?** (A boat.)

- ***SNAKES & LADDERS*** **(Refer to Master List of Questions)**

    - Say, **Because you all worked so hard this week while we learned about *McElligot's Pool*, I am going to give you each a sticker. (**Hand out lesson stickers.)

Completed ____ NOTES:

SESSION THREE

- **INTRODUCTION**

    - Say, **Let's review how we should act when we are together. When we get together, I expect you all to listen carefully and do your best. OK?** (Wait for a response.) **When I'm talking, what should you be doing?** (Listening.) **That's right! And when I call on one of you to speak, we will all listen to you. That is how we show respect for each other. It's important that we respect each other so we can all do our best.**

- **VOCABULARY ASSESSMENT**

- Say, **Today we are going to review the math words we learned last time and the time before. We are each going to take turns retelling parts of our story and using our new words.**

	Part of Story Given	Word Used
CHILD 1		
CHILD 2		
CHILD 3		
CHILD 4		

Completed ____ NOTES:

- **CONNECTING WORDS TO THE STORY**
  - Reread the story, and as you read, use the words to help the children understand the story
    - **With/Without**
      - **In the story, the boy thinks that he will catch fish with his worms, even though the farmer said it was not possible. How did the boy know the farmer was wrong?**
    - **Same**
      - **In the story, the same number of cans and bottles are on the bottom of McElligot's Pool. How many cans and bottles are on the bottom?**
    - **Short/Long**
      - **Would you rather catch a short fish or a long fish? Why?**
    - **Bigger/Smaller**
      - **Could the boy catch a big fish or a whale with his fishing rod and hook? Could he catch a small fish?**
    - **Add**
      - **Show us how to add the fish that are afraid.**

- **INSTRUCTION—Direct Mathematics Instruction (LONG/SHORT)**
  - **SHORT/LONG**
    - Use the Monkeys in a Barrel for this activity. Ask the children compare the lengths of chains of monkeys. Say, **Now everyone will get a turn to tell us which line of monkeys is long and which is short. Count the monkeys to help you figure out the length.**
      - First group: 5 versus 6

        - Second group: 2 versus 5
        - Third group: 4 versus 4 (use to reinforce “equal” from *Two Greedy Bears*)
        - Fourth group: 3 versus 4

- **WORD-BASED ACTIVITY**
    - Use the Fisherman worksheet. Say, **Now we are going to help the fisherman put his fish in the net. Draw lines to put the smaller fish in the small net. Draw lines to put the large or bigger fish in the big net.**

- ***SNAKES & LADDERS*** **(Refer to Master List of Questions)**

    - Say, **Because you all worked so hard this week while we learned about *McElligot’s Pool*, I am going to give you each a sticker.** (Hand out lesson stickers.)

Completed ____   NOTES:

Appendix B

SNAKES & LADDERS GAME

HOW TO PLAY:
Every child gets his/her own game board. Each player takes a turn spinning the spinner and advancing to the circle 1 or 2 spaces ahead. If the player can correctly answer the question for the circle that he/she lands on (which the instructor will read from the questions list), then he/she may spin once more. If the player lands on the top of a snake, the player must successfully answer the question, otherwise he/she must slide up/down the snake. Everyone who plays the game correctly and politely wins.

MASTER LIST—*SNAKES & LADDERS* QUESTIONS
Say, **First, spin the spinner and say the number you landed on out loud. Then, count to move to your next circle. Let's practice. I spun a 2. I will say, "I'm on start. I spun a 2. I move 1, 2." Now, if I'm on 3 and a I spin a 2, I say, "I'm on 3. I spun a 2. I move 4, 5." I am going to read you the word that goes with the space you landed on and a question about that word. If you answer correctly, you may spin one more time before your neighbor gets a turn. Let's play *Snakes & Ladders*!**

There are either multiple questions or different possible answers for each word in case more than one child lands on a specific word during the game.

Sample Questions

1. *Greedy* (Say, **Is this an example of being greedy?**)

    a. For his birthday, Joey brought in cupcakes to share with everyone in his classroom.
    b. Sarah took Keisha's candy bar without asking.

2. *Equal*

    Retell part of our story using the word "equal."

3. *Divide*

    Show us how you can divide the monkeys into two piles. Count to tell us how many are in each pile. Are the piles equal?

4. *Equal*

    Divide the monkeys into two equal piles. Count to be sure.

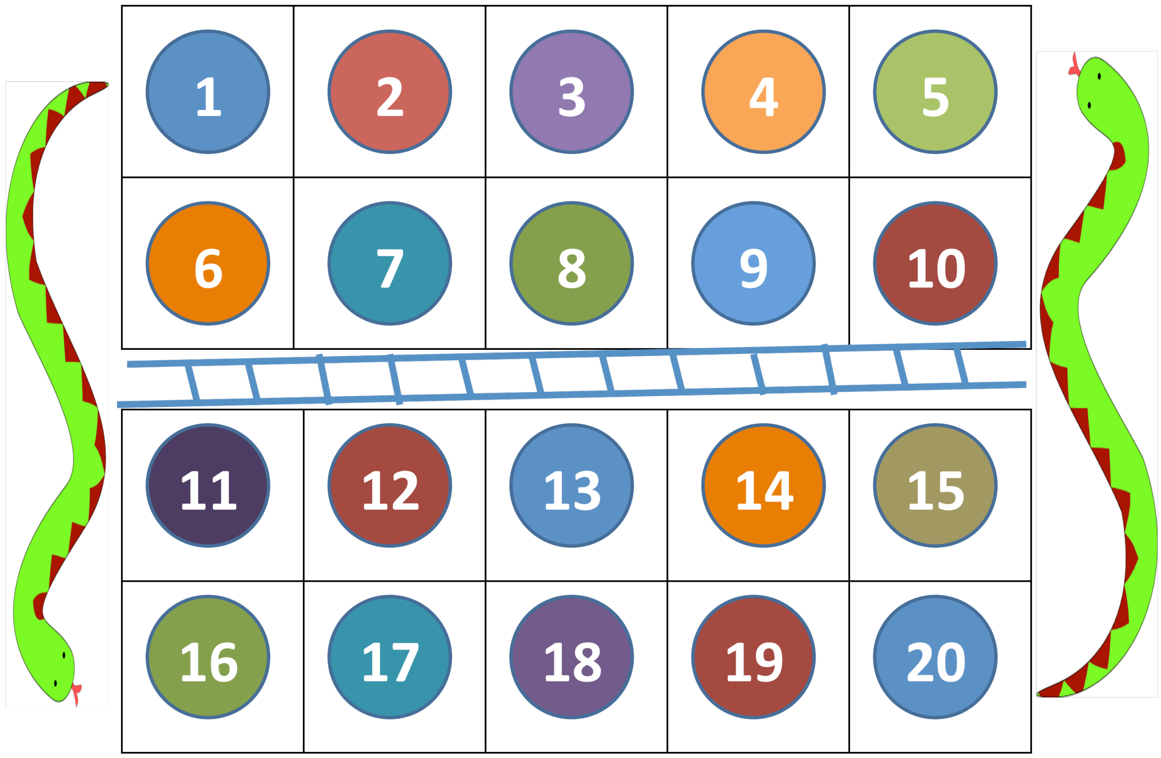

Figure B.1. *Snakes & Ladders* game board.

Appendix C

INTERVENTION FIDELITY CHECKLIST

Check off each bullet completed. Circle any portions missing from the script. Write in any deviations from instruction or questions you have in the far right column.

INTERVENTION FIDELITY

Lesson 2.2

Instructor: __________________ School:___________________ Coder: ___________________ Fidelity _____ / __33___
of √ # possible

Activity	*Script*	*Comments OR Questions*
Vocabulary Introduction	❖ **READING THE STORY** o Read through the book again, and when you get to a vocabulary word, complete the following: ❖ Say, **Who remembers what "long" means?** **Vocabulary** Skim through the story a second time to highlight the vocabulary words. Say, **Now we are going to go over some math words.** ☐ *Bigger/Smaller:* **"Bigger" means a group with more fish than the smaller group. The bigger group is also larger in size than the smaller group. The smaller group has fewer fish than the bigger group.** ☐ *Add:* **The Dog fish scared the other fish. How many fish did he scare? If we add them, we can find out. "Add" means "combine together to make a larger amount."**	Total Checks ______ # possible = 3
Vocabulary Instruction	❖ **INSTRUCTION—Vocabulary Introduction** *Bigger/Smaller*	

	Add	☐ **In the story, boy describes all kinds of fish. Some fish are big, and some fish are small. If one fish is larger than another fish, for example, the whale versus the fish with the long curly nose, you can say that it is bigger. If a fish is not as large as another fish, for example, the short fish and the fish with the long flowing whiskers, you can say that it is smaller. Also, when you look at the groups of fish, the group with more fish is the bigger group and the group with fewer fish is the smaller group. Let's say the words "bigger" and "smaller" together.** ☐ **Let's think of some other examples of the words "bigger" and "smaller." I will say two things, and I would like you to raise your hand if you can tell me which group is bigger and which thing is smaller.** • **A group of two fish and a group of seven fish** • **A group of five kids fishing and a group of ten kids fishing** • **A basket of ten worms and a basket of eight worms** ☐ **What is the word that describes the larger fish or the group with more fish in the story? What word describes the little fish or the group with fewer fish?** ☐ **In the story, the Dog fish scared the other fish when he swam toward them. If we add the fish together, we can find out how many fish were scared by the Dog fish. "Add" means "combine together to make a larger amount."** ☐ **Let's look through our story and see what we can add.** • **How many fish are looking at the boy's fish hook?** • **How many fish from the Tropics are swimming to McElligot's Pool?** • **What else could we add? What do you see? (**Have the students provide examples from the story.) ☐ **What is the word that means "combine together to make a larger amount"?**	Total Checks ______ # possible = 12

Direct Math Instruction	❖ **INSTRUCTION—Direct Mathematics Instruction (BIGGER/SMALLER, ADD)** *Bigger/Smaller* o Use the Numbers 0–25 Flashcards. Say**, Now we are going to compare big and small groups. Here are two groups. Raise your hand to tell me which is the bigger group and which is the smaller group. Count the number of objects to find out the answer.** Make the following groups using the picture sides of different cards: • **5 vs. 3** • **7 vs. 4** • **10 vs. 8** • **6 vs. 9** *Add* ☐ Next, use the Fish cards to reinforce the concept of “add.” • **Let’s practicing adding with our Fish cards.** (Give one child five Fish cards). • **Ask two children to tell a story by adding the fish. Give an example first: I will put down two fish. Now, you put down one more fish. Let’s add the fish to figure out how many we have. 2 + 1 = 3. Let’s see how we can write it. 2 plus 1 equals 3. Remember, equal means same as. So, 2 plus 1 is the same as 3.** (Give all children a turn—ONE CHECK PER TURN.)	Total Checks ______ # possible = 11

Word-Based Activity	❖ **WORD-BASED ACTIVITY (BIGGER/SMALLER)** o Use the Transportation Station worksheet. Say, **If we wanted to get across McElligot's Pool, how could we do it?** (We could use a boat.) **Now we are going to follow directions to find bigger and smaller examples of ways to get where we want to go.** o Say, **Look at the first picture. Which car is bigger? Draw a rectangle around the bigger car. Do the same thing for the next two pictures.** o Say, **Look at the first picture in the bottom row. Which picture is smaller? Do the same thing for the next two pictures. What is the last picture?** (A boat.)	Total Checks ______ # possible = 3
Snakes & Ladders	☐ Say, **First, spin the spinner and say the number you landed on out loud.** ☐ **Then, count to move to your next circle.** ☐ **Let's practice. I spun a 2. I will say, "I'm on start. I spun a 2. I move 1, 2." Now, if I'm on 3 and a I spin a 2, I say, "I'm on 3. I spun a 2. I move 4, 5."** ☐ **I am going to read you the word that goes with the space you landed on and a question about that word. If you answer correctly, you may spin one more time before your neighbor gets a turn. Let's play**	Total Checks ______ # possible = 4

	***Snakes & Ladders*!**	

Appendix D

HUMAN SUBJECTS APPROVAL LETTER

UNIVERSITY OF DELAWARE

RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE:	October 19, 2011
TO:	Nancy Jordan
FROM:	University of Delaware IRB
STUDY TITLE:	[139343-2] Developing Number Sense in Children
SUBMISSION TYPE:	Continuing Review/Progress Report
ACTION:	APPROVED
APPROVAL DATE:	October 19, 2011
EXPIRATION DATE:	October 18, 2012
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # 7

Thank you for your submission of Continuing Review/Progress Report materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.