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Developing Early Numeracy and Early Literacy Skills in Preschool Children Through a Shared Parent/Child Book Reading Intervention: A Multiple-Baseline Single Case Design Study

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by

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ABSTRACT

The present study examined the effectiveness of a shared storybook reading intervention in increasing children's early numeracy and early literacy skills through a multiple baseline single case design. Four parent-child dyads were included in the study, and children's early numeracy and early literacy skills were measured using the eNumeracy Early Math Assessments and the Preschool Early Literacy Indicators, respectively. The study also measured mathematical dialogue to determine if an increase in children's early numeracy skills is due to the intervention and not other confounding variables. Finally, the study measured intervention integrity, and parent ratings of social validity. Results of the study indicated that parent-child mathematical dialogue increased for three participants and could not be calculated for the fourth participant due to attrition. Visual analysis and hierarchical linear modeling results indicated no statistically significant early numeracy or literacy outcomes across participants. A masked visual analysis indicated that there was an observable difference in children's scores on the eNumeracy Ordinal Position measures, but none of the other outcome measures. Additionally, the majority of parents were able to implement the intervention with integrity and all parents reported high levels of social validity. The findings of this study show that the parent directed shared mathematical storybook reading intervention was effective in increasing mathematical dialogue between parents and children. Future studies should examine the impact of shared mathematical storybook reading interventions on discrete early numeracy and literacy skills specifically targeted during the book reading interventions.

CHAPTER ONE: INTRODUCTION

Mathematics achievement is an area of weakness for students across the United States because they are not meeting standard proficiency levels or performing at the same level as their international peers. The 2013 National Assessment of Educational Progress (NAEP) assessment, which covered five mathematical content areas, including (1) number properties and operations, (2) measurement, (3) geometry, (4) data analysis, statistics, and probability, and (5) algebra, and placed students into one of four achievement levels based on their performance (advanced, proficient, basic, or below basic) demonstrated that students in the US are not succeeding in mathematics (National Center for Education Statistics, 2013). The goal is for students to be performing at or above the proficient level, which indicates they are competent in the presented mathematical material. The results of the assessment revealed that fewer than half (42%) of fourth grade students scored at the proficient or advanced levels (34% and 8%, respectively), and 36% of eighth grade students scored at the proficient or advanced levels (27% and 9%, respectively). Additionally, the Program for International Student Assessment (PISA) conducted an international assessment in 2012 to measure 15-year-old student's abilities to apply mathematical concepts to real-life problems (Kelly et al., 2013). The assessment was scored on levels of 1 to 6 with a score of 5 or above indicating a student demonstrates high levels of math skills (i.e., "top performers"), and with scores of level 2 or below demonstrating low levels of math skills (i.e., "baseline level of proficiency"; Kelly et al., 2013, p. 7). The study showed that only 9% of 15-year-old students scored a level 5 or above, and 26% scored a level 2 or below. These results show that few U.S. students are meeting high mathematical standards, and more

students are performing at baseline proficiency levels when compared to the international averages (13% and 23% respectively). Collectively, these studies indicate that mathematical achievement is a concern at both the national and international levels.

In addition to few students in the U.S. meeting high mathematical standards, students' mathematical achievement is related to their overall academic outcomes, which makes low math achievement in the U.S. particularly concerning. The academic skills children possess when beginning school are predictive of their academic achievement later in life. Duncan and colleagues (2007) conducted a longitudinal study that examined the relationship between children's academic skills when they initially entered school and their later academic achievement. The authors found that early mathematics skills have the greatest predictive power of later academic achievement for children in both the domains of reading and math (Duncan et al., 2007). Overall, previous research emphasizes the importance of early intervention and prevention of mathematics skills to enhance future school success.

Early numeracy skills are not only predictive of later academic achievement (Duncan et. al., 2007), but they are also the foundation upon which more advanced mathematical skills are developed. Children's early numeracy skills are defined as a "child's fluidity and flexibility with numbers, the sense of what numbers mean, and an ability to perform mental mathematics and to look at the world and make comparisons" (Gersten & Chard, 1999, pp. 19-20). Purpura and Lonigan (2013) conducted a study to determine the specific skills that children need to develop early numeracy skills. They found that early numeracy is composed of three specific domains: numbering, relations, and arithmetic operations. These domains require children to understand counting processes and sequences, critically think about numbers and quantity, understand the association between collections of objects and numbers on a mental number line, know the

meaning of numerals, and understand how to compose and decompose specific quantities (Purpura & Lonigan, 2013). Research suggests that early numeracy skills are necessary for developing higher order mathematics and problem solving skills (Gersten & Chard, 1999), further illustrating the importance of children developing a strong foundation in early numeracy.

Research has also revealed that children who either engaged in early numeracy activities at home with their parents, or students who had a moderate to strong understanding of early numeracy concepts when entering kindergarten, had higher math achievement in the fourth and eighth grade (Mullis, Martin, Foy, & Arora, 2012). By helping young students develop a strong understanding of early numeracy skills, educators and parents have the potential to enable children to experience future success in their mathematical achievement. Specifically, early intervention and preventative measures should target early numeracy skills such as counting, quantity discrimination, and number naming which have been found to be moderate to strong predictors of mathematics achievement (Lembke & Foegen, 2009).

Although effective early numeracy interventions have been identified, few empirical studies have focused on how parents can interact with their children to help them develop early numeracy skills. Parent directed early numeracy interventions that have been examined include schools helping parents implement early numeracy interventions (Starkey & Klein, 2000), game board interventions (Ramani & Siegler, 2008; Siegler & Ramani, 2009), and storybook interventions (Hojnoski, Columba, & Polignano, 2014). Of these options, shared storybook reading, defined as parents reading mathematical storybooks with their child, is particularly promising because it incorporates both early numeracy and early literacy concepts. Previous studies have shown that shared storybook reading has been used as a way to increase mathematical dialogue between parents and children, which can impact children's early

numeracy skills (Anderson, Anderson, & Shapiro, 2004; Anderson, Anderson, & Shapiro, 2005; Flevares & Schiff, 2014; Hojnoski, Columba, & Polignano, 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013). Specifically, Hojnoski and colleagues (2014) conducted a study that examined the impact of shared parent-child storybook reading on mathematical dialogue. Previous studies have shown that high levels of mathematical dialogue between parents and children can improve children's early numeracy skills (Gunderson & Levine, 2011; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010; Suriyakham, Levine, & Huttenlocher, 2006). Hojnoski and colleagues (2014) provided parents with mathematical storybooks and reading guides to help parents incorporate math dialogue into shared book reading between parents and children. The results of the study showed that shared storybook reading could increase math dialogue between parents and children. Additionally, parent surveys demonstrated that the intervention had a high level of social validity (e.g., parents were able to implement the intervention, and found it meaningful). However, the study did not measure children's early numeracy achievement outcomes. This type of intervention also has the potential to impact children's early literacy outcomes due to the increase in shared parent-child book reading.

Problem Statement and Purpose of the Study

Given the potential of storybook interventions to increase children's academic skills in multiple domains (i.e., early numeracy and early literacy) and high reported levels of social validity, this type of intervention seems particularly promising. The purpose of this study was to empirically examine parent-child mathematical storybook interventions and the impact they have on children's early numeracy and early literacy skills, as well as the impact on parent-child mathematical dialogue. Specifically, the current study aimed to duplicate the findings of

Hojnoski and colleagues by examining mathematical dialogue, and expand on the study by exploring the impact of a storybook intervention on preschool students' early numeracy and literacy outcomes (Hojnoski et. al., 2014). Previous studies have shown that mathematical dialogue increases between parents and children when they read mathematical storybooks (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013), and that mathematical dialogue is correlated with young children's early numeracy skills (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). However, no studies have been conducted that examine the impact of parent-child mathematical storybook reading on children's early numeracy achievement. Additionally, parents typically report that they believe children's early literacy skills are more important than children's early numeracy skills (Cannon & Ginsburg, 2008; Ramani, Rowe, Eason, & Leech, 2011; Sonnenschein et al., 2012), and that they spend more time engaging in early literacy activities with their children (Chang, Sandhofer, Adelchanow, & Rottman, 2011; Hunt & Hu, 2011). Incorporating mathematical concepts into storybook reading may increase parent's willingness to engage in mathematical activities with their child, especially if the intervention has the potential to increase children's early literacy skills as well. The current study measured the impact of shared book reading between parents and children on mathematical dialogue, as well as the impact on children's early numeracy and literacy achievement.

Research Questions

This study examined the following research questions:

1) To what degree does a parent-led intervention increase mathematical dialogue between parents and children (when compared to baseline observations)?

a. Hypothesis: Shared mathematical storybook reading will increase mathematical dialogue between parents and children. Previous studies have shown that reading storybooks including mathematical concepts increases mathematical dialogue between parents and their children (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013).

2) To what degree does a parent-led intervention improve children's early numeracy skills (e.g., cardinality, ordinality, number naming, matching numerals with quantity, and partitioning equal quantities)?

a. Hypothesis: Shared mathematical storybook reading between parents and children will increase children's early numeracy skills in the areas of cardinality, ordinality, number naming, matching numerals with quantity, and partitioning equal quantities. Although no previous studies have measured these specific early numeracy outcomes, previous studies have indicated that reading mathematical storybooks leads to an increase in mathematical dialogue (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013), and that mathematical dialogue between parents and children is predictive of children's early numeracy skills (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). Therefore, one would expect to see an increase in children's early numeracy skills based on the current intervention. Additionally, the lessons generated for each storybook focus on cardinality, number naming, matching numerals with quantity, and partitioning equal quantities. Ordinality is

only taught directly in one lesson, but is an applied skill that could develop through other lessons as well.

3) To what degree does a parent-led intervention improve children's early literacy skills (e.g., phonological awareness and vocabulary)?
    a. Hypothesis: Shared mathematical storybook reading between parents and children will increase children's early literacy skills in the area of vocabulary but not phonological awareness (Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988). The proposed intervention will use a modified version of dialogic reading to increase mathematical dialogue between parents and children. This hypothesis is based on previous studies that have shown that dialogic reading techniques have a positive impact on children's vocabulary but no discernable effects on their phonological awareness (What Works Clearinghouse, 2007).
4) What is the level of intervention acceptability of the early numeracy intervention?
    a. Hypothesis: Parents will provide high ratings of intervention acceptability for this intervention (Hojnoski et al., 2014). In a previous study, Hojnoski and colleagues (2014) measured the parent's level of intervention acceptability after completing the mathematical storybook reading intervention, and found that the majority of the participants found the intervention appropriate, acceptable, effective, and easy to implement (Hojnoski et al., 2014). Additionally, because parents typically think that children's early literacy skills are more important than early numeracy

skills (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012), an intervention that allows a parent to incorporate both early literacy and early numeracy skills may be more acceptable than an intervention focusing solely on children's early numeracy skills.

5) To what degree was the intervention implemented with integrity?
    a. Hypothesis: Parents will implement the intervention with a high rate of intervention integrity given the evidence-based practices used to increase intervention integrity (i.e., parent training, lesson plan packets, audio recording intervention sessions). Previous research has shown that monitoring procedures (Hook & DuPaul, 1999; Powell-Smith, Stoner, Shinn, & Good, 2000) and training parents (Persampieri, Gortmaker, Daly, Sheridan, & McCurdy, 2006; Sterling-Turner, Watson, Wildmon, Watkins, & Little, 2001) can both increase the fidelity of intervention implementation.

Definition of Key Terms

Early Numeracy, Number Sense, and Informal Mathematical Skills

Early numeracy, number sense, and informal mathematical skills are defined in the research literature as the foundational skills that children need in order to develop mathematical competence (Powell & Fuchs, 2012). Gersten and Chard (1999) expand upon this definition by stating that number sense is "the child's fluidity and flexibility with numbers, the sense of what numbers mean, and an ability to perform mental mathematics and to look at the world and make comparisons" (p. 19-20). Although number sense, early numeracy, and informal mathematical skills are often used interchangeably in the research literature, the term early numeracy will be used for the duration of this study because that is the term most often used in the educational

research literature. Research suggests that children's early numeracy skills are composed of three main factors: numbering, relations, and arithmetic operations (NRC, 2009; Purpura & Lonigan, 2013). These constructs are defined further in the sections below.

Numbering

Numbering is one of the three main factors of early numeracy, and is defined as a child's understanding of counting rules, processes, sequences, and their ability to critically think about numbers and quantity. Skills included in the numbering domain are verbal counting, counting forward and backward, identifying counting errors, one-to-one correspondence, cardinality, counting a set of objects without touching or manipulating the set, counting subsets, subitizing, and estimation (Purpura & Lonigan, 2013).

Relations

Relations is also a component of early numeracy, and it is defined as a child's understanding of the association between sets/collections of objects, numerals, or numbers on a mental number line (Purpura & Lonigan, 2013). The skills in this domain of early numeracy include ordinal numbers, relative size, number comparison, set comparison, number order, sequencing, set reproduction, numeral identification, and numerals.

Arithmetic Operations

Arithmetic operations are also a component of children's early numeracy skills, and they are defined as "the understanding of the ways in which groups are composed and decomposed by differentiating sets and subsets" (Purpura & Lonigan, 2013, p. 182). Skills included in arithmetic operations include addition and subtraction with objects, story problems, initial equivalence, two-set addition, equivalent sets, number composition/ decomposition, and number combinations.

Cardinality

Cardinality is a concept included in the numbering factor of early numeracy. Specifically, cardinality refers to a child's understanding that, when counting a set of objects, the last number named represents the total number of items in the set (Powell & Fuchs, 2012). When children learn this concept, it helps them understand the importance and purpose of counting.

Ordinality

Ordinality is a concept included in the relations factor of early numeracy (Purpura & Lonigan, 2013). Specifically, ordinality (or ordinal number) signifies the position where a number or object falls in relation to other numbers or objects (e.g., first, second, third, etc.; Cross, Woods, and Schweingruber, 2009).

Number Recognition

Number recognition is a concept included in the relations factor of early numeracy (Purpura & Lonigan, 2013). This skill requires children to identify written numbers, and it partially mediates the relationship between early numeracy skills and formal mathematical knowledge (i.e., mathematical calculation; Purpura, Baroody, & Lonigan, 2013).

Matching Numerals with Quantities

Matching numerals with quantities is a task that requires children to match a written numeral to an array of objects or images. This skill is a concept in the relations factor of early numeracy (Purpura & Lonigan, 2013), and helps to mediate the relationship between early numeracy skills and formal mathematical knowledge (i.e., mathematical calculation; Purpura, Baroody, et al., 2013).

Partitioning Equal Quantities

Partitioning equal quantities is a task that requires children to view an array of objects and to divide them equally among two people, or to view arrays of objects for two people and decide if their arrays contain equal amounts. This task fits within the arithmetic operations of early numeracy (Purpura & Lonigan, 2013). Table 1 shows the three domains of early numeracy, the specific skills in each domain, and the name of the assessment that will be used in the present study to measure each construct.

Table 1

Domains of Early Numeracy

Numbering	*Relations*	*Arithmetic Operations*
A child's understanding of counting rules, processes, sequences, and their ability to critically think about numbers and quantity.	A child's understanding of the association between sets/ collections of objects, numerals, or numbers on a mental number line	"The understanding of the ways in which groups are composed and decomposed by differentiating sets and subsets" (Purpura & Lonigan, 2013, p. 182).
Early Numeracy Assessments By Domain		
Cardinality	Ordinality Number Recognition Matching Numerals with Quantities	Partitioning Equal Quantities

Dialogic Reading

Dialogic reading is a shared storybook reading method that allows a child to interact and engage with a story as they read with an adult. Studies have shown that dialogic reading is an intervention method that increases children's language and literacy skills (Lonigan et al.,1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988). When implementing dialogic reading techniques with a child, an adult uses a variety of prompts (i.e., completing a sentence, recalling events, open-ended questions, asks the child to relate the

story to events in their life, or asks who, what, when, where, why, and how questions) to engage the child with the story. After providing a prompt, the adult will provide the child with feedback regarding the answer, add additional information to the child's response, and repeat the prompt to make sure that the child has learned something from the adult's feedback and additional information (What Works Clearinghouse, 2007).

Pre-school Students

Pre-school students are children between the ages of four and five years old.

Voluntary Pre-Kindergarten

Voluntary Pre-Kindergarten (VPK) is a preschool program for children between the ages of four and five. This program is funded by the Florida legislature, and children must be Florida residents between the ages of four and five to register for these services. The program is focused on helping children develop reading, math, social, and cognitive skills so they have the necessary skills when they begin kindergarten.

Parental Involvement

Parental involvement can be broadly defined as "parents' or caregivers' investment in the education of their children" (LaRocque, Kleiman, and Darling, 2011, p. 116). More specifically, parental involvement refers to numerous activities and relationships between families, schools, and communities (Epstein, 2011). Epstein (2011) defines six specific types of parental involvement that include the following: (a) assisting parents with developing positive and supportive environments for their children at home, (b) having parents assist with educational activities at home, school, or in the community, (c) communication between teachers and parents, (d) allowing parent involvement with school wide decision-making, (e) teaching parents how to help their children with school work at home, and (f) strengthening school

programs through community resources and services (Epstein, 2011). Parent involvement both at home (Anders, Rossbach, Weinert, Ebert, Kuger, Lehrl, & Maurice, 2012; Blevins-Knabe & Musun-Miller, 1996; Kleemans, Peeters, Segers, Veroheven, 2012; LeFevre, Skwarchuck, Smith-Chant, Fast, Kamawar, & Bisanz, 2009; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010; Manolitsis, Georgiou, & Tziraki, 2013; Niklas & Schneider, 2013; Skwarchuk, 2009; Skwarchuk, Sowinski, & LeFevre, 2014;Vandermaas-Peeler, Nelson, Bumpass, & Sassine, 2009) and at school (Blevins-Knabe & Musun-Miller, 1996; Fan & Chen, 2001; Galindo & Sheldon, 2012; Hill & Taylor, 2004; Kleemans, Peeters, Segers, Veroheven, 2012; LeFevre, Skwarchuck, Smith-Chant, Fast, Kamawar, & Bisanz, 2009; Miedel & Reynolds, 1999; Powell, Son, File, & San Juan, 2010; Sheldon & Epstein, 2005; Wade, 2004; Yap & Enoki, 1995) has a positive impact on children's early numeracy and mathematical skills.

Math Talk (or Math Dialogue)

Math talk or math dialogue occurs when an adult (i.e., teacher or parent) and children discuss math related topics (Boonen, Kolkman, & Kroesbergen, 2011; Gunderson & Levine, 2011; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010; Suriyakham, Levine, & Huttenlocher, 2006). Research shows that math talk between parents and children is significantly related to children's performance on early numeracy tasks (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). In previous studies, math talk has been measured through qualitative analysis, and involves coding parent-child dialogue into discussions related to early numeracy and mathematics, and unrelated discussions.

Multiple Baseline Design

A multiple baseline research design is a type of single case experimental design that employs experimental control by staggering the baseline and intervention phases of the study over time. By starting the intervention for one student, while the remainder of the students stay in the baseline phase, one would expect to see a change in performance for the student receiving treatment but not for the students in baseline. This pattern suggests that the change in performance is likely due to the intervention and not extraneous variables. In addition to it's methodological rigor, a multiple baseline design allows the measurement of change in student knowledge and skills once the intervention begin. Finally, a multiple baseline design can be used to conduct statistical analyses that measure the effectiveness of treatment for both individual students and across students (e.g., hierarchical linear modeling).

Significance of the Study

The results of this study are significant for a number of reasons. First, no studies to date have examined the effect of parent-child mathematical storybook reading on children's early numeracy achievement. Additionally, no studies have examined the impact of this type of intervention on children's early literacy achievement. By measuring both early literacy and early numeracy constructs, this study has given educators and parents a better understanding of how reading mathematical storybooks impacts children's early achievement. Previous studies have shown that there is a connection between parent-child mathematical storybook reading and the increase of parent-child mathematical dialogue (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013), and that mathematical dialogue can increase children's early numeracy skills (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et

al., 2006). Therefore, this research has expanded on previous studies by determining if an increase in mathematical dialogue between parents and children, in the context of shared mathematical storybook reading, impacts children's early numeracy skills. In addition to measuring mathematical dialogue and children's early numeracy skills, this study investigated if applying dialogic reading to mathematical storybook reading will increase children's early literacy skills because previous research has shown positive literacy outcomes when using dialogic reading (Lonigan et al.,1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988). If both early literacy and early numeracy skills are impacted by this intervention, this research also has the potential to increase social validity of the intervention for parents if positive results are found for both sets of academic skills. In addition, if parents are able to implement this intervention with integrity, it has the potential to be a useful intervention for schools to recommend to parents. Finally, by using a single case, multiple baseline design the study allows for a rigorous investigation of the research questions.

CHAPTER TWO: LITERATURE REVIEW

Children's number sense and early numeracy skills are predictive of their later academic achievement. Therefore, helping children to develop a strong foundation in these skills is imperative to preventing future academic difficulties. This chapter will provide a review of the literature regarding number sense and early numeracy, parental involvement, and early numeracy interventions. Specifically, the first part of this chapter will provide a definition of early numeracy and number sense, the factors and sub skills that compose early numeracy, how early numeracy and number sense develop, and their relation to later mathematical achievement. Next, parental involvement will be defined, and the importance of parental involvement at school, parental involvement at home, and parental beliefs related to early numeracy will be discussed to highlight the relation of these factors to children's early numeracy achievement. Finally, the chapter will close with a review of the different types of early numeracy interventions, including school assisted, game board, and story book interventions.

Early Numeracy and Number Sense

The first section of this chapter will discuss the definitions of number sense and early numeracy, and the various sub-skills that are encompassed by number sense and early numeracy. Additionally, this section will discuss how number sense and early numeracy develop as children age, and how these skills relate to later mathematical achievement.

Definition

Research has demonstrated that number sense is a skill that is present at birth (in a very primitive form), and improves with age. Cognitive scientists and math educators do not explain number sense in exactly the same way, which makes the construct hard to define (Berch, 2005). Berch (2005) reported almost 30 different definitions of number sense present in the research literature. Cognitive scientists define number sense as a "primitive sense of number" (Libertus, Feigenson, & Halberda, 2011, p. 1293), which produces imperfect estimations of numbers that can be manipulated and used for computations of addition, subtraction, division, multiplication, and greater than/ less than comparisons (Libertus et al., 2011). The National Council of the Teachers of Mathematics (1989) describe number sense as a flexible understanding of numbers, measurement, and the relationships between numbers and their relative size (NCTM, 1989). In addition to number sense having a variety of definitions, there are other terms in the research literature that are used synonymously with number sense. Two terms that are commonly used as alternatives for number sense are early numeracy and informal mathematical knowledge. Powell and Fuchs (2012) define early numeracy as "the early numerical competencies that are foundational to building competence in mathematics" (pg. 1) and indicate that early numeracy and number sense are often used interchangeably in research. Informal mathematical knowledge is explained by Purpura and Lonigan (2013,) as mathematical skills children learn before entering school, through their environment and play situations, that do not involve written numerals, mathematical symbols, or formal math procedures.

Despite the disconnect between fields regarding the definition of number sense, there are some overarching themes that can be used to define number sense that are nicely illustrated by Gersten and Chard (1999). They state that number sense is "the child's fluidity and flexibility

with numbers, the sense of what numbers mean, and an ability to perform mental mathematics and to look at the world and make comparisons" (p. 19-20). This definition is frequently used in the literature and will be adapted for the current study. These researchers also compare number sense to phonemic awareness in reading because it is seen as the foundation upon which more advanced mathematical skills are developed. Additionally, they note that number sense is necessary but not sufficient for developing higher order mathematics and problem solving skills (Gersten & Chard, 1999). Although number sense, early numeracy, and informal mathematical skills are often used interchangeably in the research literature, the term early numeracy will be used for the duration of this paper because that is the term most often used in the educational research literature.

Components of Early Numeracy

There is little consensus among researchers regarding the number of factors contributing to early numeracy skills; different studies report that early numeracy is based on a 3 factor model, a 2-factor model, and a 1 factor model. The *National Research Council (NRC) Mathematics Learning in Early Childhood: Paths Towards Excellence and Equity* report (NRC, 2009) identifies numbering, relations, and arithmetic operations as the core skills of early numeracy. Numbering is defined as a child's "knowledge of the rules and processes of the counting sequence and the ability to obtain quantity in a flexible manner" (Purpura & Lonigan, 2013, p. 180). Numbering skills include verbal counting, counting forward and backward, identifying counting errors, one-to-one correspondence, cardinality, counting a set of objects without touching or manipulating the set, counting subsets, subitizing, and estimation. Relations is defined as understanding "how two or more items (collections or numbers) are connected or relevant to each other and the association between the numbers on the mental number line"

(Purpura & Lonigan, 2013, p. 180). Skills in the relations category include ordinal numbers, relative size, number comparison, set comparison, number order, sequencing, set reproduction, numeral identification, and numerals. Finally, arithmetic operations are defined as "the understanding of the ways in which groups are composed and decomposed by differentiating sets and subsets" (Purpura & Lonigan, 2013, p. 182). Skills included in arithmetic operations include addition and subtraction with objects, story problems, initial equivalence, two-set addition, equivalent sets, number composition/ decomposition, and number combinations.

Based on a synthesis of the literature, it is unclear whether numbering, relations, and arithmetic operations are "separate aspects of [early] numeracy skills or simply different means of assessing a general-[early]-numeracy skill construct" (Purpura & Lonigan, 2013, p. 182). Pupura and Lonigan (2013) conducted a study to further examine the structure of numbering, relations, and arithmetic operations, and to assess how these constructs relate to each other (Purpura & Lonigan, 2013). The authors assessed 393 preschool children across 45 public and private preschool settings. The children ranged in age from 3 to 6 years old and were assessed using the Preschool Early Numeracy Skills (PENS) Test (Purpura, 2010; Purpura & Lonigan, 2013). The subtests in the PENS Test include multiple activities assessing numbering, relations, and arithmetic operations.

Once the data were collected, the researchers used factor analysis to examine the factor structure of early numeracy skills, compare the accuracy of various fact or models, and to determine if the early numeracy factor structure differed based on a preschool student's age (Purpura & Lonigan, 2013). The researchers found that the tasks administered during subtests for numbering, relations, and arithmetic operations each significantly loaded on their respective factors, and shows that "each factor represents a unidimensional construct" (Purpura & Lonigan,

2013, p. 195). They also found that the tasks were representative of their domains and that the constructs fit the data. Next they found that the three-factor model of early numeracy characterized the data better compared to other models (e.g., 2 factor models and 1 factor models). This suggests that numbering, relations, and arithmetic operations are correlated but separate factors that make up children's early numeracy skills. Finally, the authors showed that children's early numeracy skills are composed of the same factors and skills regardless of age (Purpura & Lonigan, 2013). The findings from this study were important because they suggest that a three factor model of early numeracy is likely the most accurate representation compared to other models that have been proposed.

Development and Importance of Early Numeracy Skills for Achievement

There is evidence that early numeracy begins to develop at a very young age. For example, infants have the ability to discriminate between differing quantities and sizes of objects by the time they reach 4-6 months of age. Bannon, Lutz, and Cordes (2006) used a habituation task with 6-month-old infants and found that babies could discriminate changes in the area of an Elmo face, but this ability was dependent on a ratio. The infants were successfully able to discriminate area with a ratio of 1:4, 1:3, and 1:2 but not a ratio of 2:3. Additionally, Xu and Spelke (2000) conducted a study examining infants' abilities to discriminate between arrays of dots. They also used a habituation task, and found that infants could discriminate between a ratio of 1:2 (e.g. 8 versus 16 dots) but not a ratio of 2:3 (e.g. 8 versus 12 dots). Finally, studies have shown that infants have expectations about numbers. Wynn (1992) conducted a study where she placed a doll on a stage, hid the doll behind a screen, and then placed another doll behind the same screen while an infant watched. The purpose of this was to simulate the addition of two objects (i.e. 1+1=2). When the screen was taken away, it revealed either one doll (simulating that

1+1=1, i.e. an incorrect solution) or two dolls (simulating 1+1=2, i.e. a correct solution). The infants looked longer when the solution revealed one doll, indicating that they were surprised by the results. Further research has been done on this topic by Berger and colleagues (2006) in which infants' brain activity was monitored (through event-related potentials) while performing the same task. The researchers found that infants looking time and brain activity was greater during the incorrect solution and that infants patterns of brain activity were similar to adults' patterns of brain activity when they observed incorrect mathematical equations.

In addition to early numeracy being present very early in life, these skills improve as children age (Halberda & Feigenson, 2008; Odic, Libertus, Feigenson, & Halberda, 2013) and early number sense abilities are predictive of later mathematics achievement (Jordan, Kaplan, Locuniak, & Ramineni, 2007; Libertus, Fiegenson, & Halberda. 2011; Mazzocco, Feigenson, & Halberda, 2011). For example, Halberda and Fiegenson (2008) conducted a study examining how numeracy skills develop as children increase in age. The researchers conducted a cross sectional study with 3-, 4-, 5-, and 6-year-old children and adults, and there were 16 participants included for each age group (Halberda & Fiegenson, 2008). The children and adults were tested using a numerical discrimination task where they were asked which of two characters (i.e., Big Bird and Grover) had more items. The items were displayed on a computer screen, with Big Bird's items in one box and Grover's in the other, for 2,000 milliseconds (Halberda & Fiegenson, 2008). Based on data gathered during pilot testing, this gave the participant enough time to compare each character's items, but not to count. Participant responses during the discrimination task were used to calculate Weber fractions, defined as "the smallest numerical change to a stimulus that can be reliably detected," for each age group (Halberda & Fiegenson, 2008, p. 1457). Weber fractions were used as the outcome measure in this study, which allowed

the researchers to determine the smallest ratio of numbers that an age group could reliably discriminate. The researchers used statistical modeling techniques to examine the trend of participants' Weber fractions over time. Included in the models were Weber fractions of 6-month-old infants, gathered from previous studies (i.e., Lipton & Spelke, 2003; Xu & Spelke, 2000), as well as the data from the 3-, 4-, 5-, and 6-year-olds, and adults from the current study (Halberda & Fiegenson, 2008). However, the statistical modeling methods also allowed the researchers to predict Weber fractions for age ranges that were not included in the study (e.g., ages seven through eighteen). The results showed that a person's ability to discriminate between quantities improves with age, and then becomes stable in adulthood. The data models also showed that, even after formal instruction in math has started, a child's numeracy skills continue to develop and improve until late adolescence (Halberda & Fiegenson, 2008). A follow-up study conducted by Odic and colleagues (2013) found similar results, supporting the idea that numeracy skills develop as children age (Odic et al., 2013).

Additionally, early numeracy abilities are predictive of later mathematics achievement (Jordan et al., 2007; Libertus et al., 2011; Mazzocco et al., 2011). A longitudinal study by Mazzocco and colleagues (2011) tested a sample of preschool children (n = 17) through a quantity discrimination task. The children were then evaluated again in kindergarten, first, or second grade, and administered a standardized math test (Test of Early Mathematics Ability – Third Edition [TEMA-3]), an intelligence test (Weschler Abbreviated Scale of Intelligence [WASI]), and rapid automatized naming tasks for colors, numbers and letters. The researchers then conducted linear regression models to determine if number sense in preschool predicted children's performance on these later assessments. The results showed that number sense was predictive of later mathematical achievement on the TEMA-3 and rapid automatized naming of

numbers, but not the other measures. This illustrates that number sense is predictive of mathematics ability even when it is measured several years prior to children formally starting school.

Duncan and colleagues (2007) examined the relationships between key components of school readiness, specifically academic, attention, and social-emotional skills at the beginning of kindergarten, and later reading and mathematics performance in school through a meta-analysis. Six large-scale longitudinal data sets were used in the study, and these data sets all included measures of early academic skills, attention, socioemotional skills, behavior, and later achievement outcomes. The data sets included in the study were: the Early Childhood Longitudinal Study – Kindergarten Cohort (n = 21,260), the children of the National Longitudinal Survey of Youth (n = 1,756), the NICHD Study of Early Child Care and Youth Development (n = 2,816), the Infant Health and Development Program (n = 985), the Montreal Longitudinal-Experimental Preschool Study (n = 1,928), and the 1970 British Birth Cohort Study (n = 11,200; Duncan et. al., 2007). Initial measures were conducted at "school entry" and the samples of children ranged in age from 5 to 6 years (Duncan et. al., 2007). Samples were collected from a variety of locations including two nationally representative samples of US children, two multisite studies of US children, a sample from Great Britain, and a sample from Canada. Initial measures of child performance included a variety of standardized tests, rating scales, and observations filled out by teachers and parents (Duncan et. al., 2007). Follow up measures were achievement tests in reading and math, and these assessments were conducted when children were between the ages of eight and fourteen years; because the researchers synthesized data from six different large scale studies, the follow up measures were administered at different time points depending on the data set. The researchers controlled for relevant family

and child variables that could potentially impact children's outcomes, such as socioeconomic status, child gender, age, etc. Regressions were used to determine which initial set of skills was most predictive of later achievement (Duncan et. al., 2007). The study indicated that early numeracy skills at school entry were the most robust predictors of mathematics and reading achievement between the ages of eight and fourteen years as measured on standardized tests for reading (i.e., Achievement Test Reading Item Response Theory (IRT), Peabody Individual Achievement Tests (PIAT) Reading Recognition, Woodcock-Johnson Psycho-Educational Battery – Revised (WJ-R) Reading, Verbal Skills, and the Edinburgh Reading Test) and for Math (i.e., Achievement Test Math IRT, PIAT Math, WJ-R Math, Number Knowledge Test, and the University of Bristol Math Test; Duncan et. al., 2007). Specifically, early numeracy skills were more than two times as predictive of later achievement as early reading skills, and four times as predictive of later achievement as children's attention, with average standardized coefficients of 0.33, 0.13, and 0.07 for math, reading, and attention, respectively. Additionally, while early literacy skills were not predictive of later math achievement (average standardized coefficient = 0.10), early numeracy skills were predictive of both later reading (average standardized coefficient = 0.26) and math skills (average standardized coefficient = 0.42; Duncan, et. al., 2007).

Another study, conducted by Purpura, Baroody, and Lonigan (2013), examined which early numeracy skills best predict later mathematical achievement. The researchers acknowledge that early numeracy skills may not have a direct effect on formal mathematical knowledge. Instead, they suggest that another set of skills that connect early numeracy skills to written number symbols, referred to in the study as numeral knowledge, may serve as a mediator between formal mathematical and early numeracy knowledge (Purpura, Baroody, et al., 2013).

The researchers conducted a longitudinal study with preschool children to test this hypothesis. Data was collected from 393 preschool children in the first year of the study, and then retested 206 of the same children 1 year later. The children ranged in age from 3 to 6 years, and the children were assessed on formal, informal, and numeral knowledge tasks (Purpura, Baroody, et al., 2013). The early numeracy knowledge tasks included activities such as verbal counting (child would count as high as they could), one to on counting (counting a set of objects), cardinality (indicating the total number of objects counted), subitizing (indicating how many objects in a set without counting), set comparison (identifying which of four sets of dots had the most or the fewest), and story problems containing simple addition and subtraction situations (e.g. "Johnny had one cookie and his mother gave him one more cookie, how many cookies did he have now?"; Purpura, Baroody, et al., 2013, p. 456). The numeral knowledge tasks included identifying written numbers, and matching a set of dots with a numeral or a numeral with a set of dots. The formal knowledge tasks included formal addition problems, and the Woodcock-Johnson III Calculation subtest (Purpura, Baroody, et al., 2013). The early numeracy and numeral knowledge tasks were administered at time one, and the formal knowledge task was administered at time two. The results of the study showed that the relationship between early numeracy and formal mathematical knowledge is mediated by children's numeral knowledge (Purpura, Baroody, et al., 2013). This suggests that children need to be able to identify written numerals and understand the relationship between written numerals and their quantity in order to develop formal mathematical knowledge.

Collectively, these studies show the importance of children developing a strong mathematical foundation at an early age. By improving children's early mathematical knowledge, parents and educators have the potential to improve children's mathematics and

overall achievement as they progress through school. The next section of this chapter will examine the impact of parental involvement on children's early numeracy skills.

Parental Involvement

Parental involvement can be broadly defined as "parents' or caregivers' investment in the education of their children" (LaRocque et al., 2011, p. 116). More specifically, parental involvement refers to numerous activities and relationships between families, schools, and communities (Epstein, 2011). Epstein (2011) defines six specific types of parental involvement that include the following: (a) assisting parents with developing positive and supportive environments for their children at home (parenting), (b) having parents assist with educational activities at home, school, or in the community (volunteering), (c) communication between teachers and parents (communicating), (d) allowing parent involvement with school wide decision-making (decision-making), (e) teaching parents how to help their children with school work at home (learning at home), and (f) strengthening school programs through community resources and services (collaborating with the community; Epstein, 2011). This section will focus on the importance of parental involvement in the context of early numeracy. First, research describing parent involvement at school and its relation to mathematics achievement will be outlined. Second, research outlining how parent involvement in the home environment has been linked specifically to early numeracy outcomes will be described. Finally, parental attitudes towards children's mathematical skills and implications of these attitudes will be discussed.

Parental Involvement at School

The research literature has established that parent involvement in their children's education is correlated with academic success (Fan & Chen, 2001; Galindo & Sheldon, 2012;

Hill & Taylor, 2004; Miedel & Reynolds, 1999; Powell et al., 2010; Sheldon & Epstein, 2005; Wade, 2004; Yap & Enoki, 1995). Additionally, research has illustrated that parental involvement in children's mathematics education has positive impacts on their math and early numeracy achievement (Blevins-Knabe & Musun-Miller, 1996; Kleemans et al., 2012; LeFevre et al., 2009; Sheldon & Epstein, 2005). A study conducted by Powell and colleagues (2010) examined the connection between parent-school relationships and the academic and social outcomes of pre-school children at the end of the year. The authors define parent-school relationships as a two-dimensional construct including participating and volunteering for school events (i.e. parental school involvement) and parental perceptions of a teacher's responsiveness to the child and parent (i.e. perceived teacher responsiveness; Powell et al., 2010). Participants in the study were 13 preschool teachers from 12 elementary schools in the Midwest, and 140 children and their parents. The researchers used the Peabody Picture Vocabulary Test – III, the Woodcock Johnson III Tests of Achievement: Letter Word Recognition, the Woodcock Johnson III Tests of Achievement: Applied Problems, and the Social Skills Rating System (Powell et al., 2010). Parent interviews were used to collect demographic data during the fall and spring to measure parental school involvement, perceived teacher responsiveness, and parental home involvement. The participating teachers filled out the Social Skills Rating System for each of their students. All teacher and student measures were conducted in both the fall and the spring, which allowed the researchers to statistically control for children's initial academic and social skill levels at the beginning of the preschool year (Powell et al., 2010).

The results of this study illustrated that parental school involvement predicted children's social skills, classroom behavior, and their mathematics achievement (Powell et al., 2010). Additionally, perceived teacher responsiveness had a positive impact on children's early reading

and social skills, and a negative impact on problem behaviors (Powell et al., 2010). These findings were present even when statistically controlling for quality of teacher/ child interactions, parent involvement at home, parent education level, child race/ ethnicity, and children's academic skills at the beginning of the year. Parent involvement at home did not significantly predict any of the child outcome measures. This study demonstrates the importance of parental school involvement on children's academic and social skills.

In addition to parent involvement having a positive impact on academic and social skills broadly, research has shown that parental involvement has a positive impact specifically on math and early numeracy achievement (Blevins-Knabe & Musun-Miller, 1996; Kleemans et al., 2012; LeFevre et al., 2009; Sheldon & Epstein, 2005). Sheldon and Epstein (2005) conducted a study examining the types of family and community involvement practices that had a positive influence on students' mathematics achievement. Eighteen schools in various states agreed to participate, and the schools were highly diverse including a variety of grade levels (n = 10 elementary schools, and n = 8 middle or high schools), locations (inner city, urban, suburban, and rural), sizes (ranging in size from 124 to 1,280 students), and student demographics (ranging from 4.8% to 88% students enrolled in free and reduced lunch, and 0% to 44% students enrolled in English as a Second Language). Schools provided aggregated mathematics performance data, from standardized tests and student report cards, for a specific grade level of their choice. This data was reported for two consecutive school years, and report card data was examined for fall and spring semesters of both years. The schools provided data for grade levels 3 through 9 with the majority of secondary level school data coming from middle schools. In addition to school characteristics and student mathematics achievement, the researchers also collected data on schools utilization of a variety of partnership practices focused on mathematics. These practices

included (a) providing parent workshops, (b) distributing teacher contact information, (c) scheduling parent teacher conferences, (d) recognizing students for mastering new math concepts (e.g., sending home a certificate), (e) helping students understand how math can be applied outside of school (e.g., discussing math with parents or organizing presentations to demonstrate how math is used by professionals), (f) encouraging parents and other community members to be involved in school math activities, and (g) providing families with math activities to do at home or to do at school on Saturdays (Sheldon & Epstein, 2005). The researchers found that, when controlling for student's prior achievement and school level, two of the fourteen partnership practices were related to students' mathematics achievement. Specifically, assigning math homework that requires discussion and interaction with their family and offering mathematics game packets or lending library materials for students to use at home were both significantly related to math achievement outcomes. This study suggests that subject-specific, family involvement activities in math are positively associated with students' mathematics achievement (Sheldon & Epstein, 2005).

Overall, these studies illustrate that parent involvement is important both for children's overall academic success (Fan & Chen, 2001; Galindo & Sheldon, 2012; Hill & Taylor, 2004; Miedel & Reynolds, 1999; Powell et al., 2010; Sheldon & Epstein, 2005; Wade, 2004; Yap & Enoki, 1995) as well as mathematical and early numeracy achievement (Blevins-Knabe & Musun-Miller, 1996; Kleemans et al., 2012; LeFevre et al., 2009; Sheldon & Epstein, 2005). By engaging families in their children's education and providing subject-specific family involvement activities in math, educators can potentially increase children's mathematical achievement.

Parental Involvement at Home

In addition to research establishing a link between parent-school relationships and parent involvement and math outcomes in third grade and beyond, studies have also shown the importance of parental-involvement at home with developing young children's early numeracy skills (Anders et al, 2012; Blevins-Knabe & Musun-Miller, 1996; Kleemans et al., 2012; LeFevre et al., 2009; Levine et al., 2010; Manolitsis et al., 2013; Niklas & Schneider, 2013; Skwarchuk, 2009; Skwarchuk et al., 2014;Vandermaas-Peeler et al., 2009). One study, conducted by LeFevre and colleagues (2009), examined the frequency of specific, numeracy related activities and indirect numeracy activities (where numeracy skills are not the focus but they could be included) in children's home environments. The study included 146 parents and children from two different cities in Canada, and the children were distributed across Kindergarten through Grade 2. Parents completed surveys that gathered information on demographic characteristics, and frequency of involvement in math and reading activities at home. Parents were asked to report how frequently they engaged in each of 40 activities on a 5 point scale ranging from 0 (did not engage in the activity) to 4 (the activity occurred almost daily; LeFevre et al., 2009). Children were assessed using the Numeration, Addition, and Subtraction subtests of the KeyMath Test – Revised, Form B, a single digit addition task to measure fluency, the Peabody Picture Vocabulary Test, 3rd Edition (PPVT-III), and a spatial memory task using a computerized version of the Corsi blocks task (LeFevre et al., 2009).

The results showed that parents reported engaging in literacy activities, such as writing letters and identifying letter names and sounds, more frequently than numeracy activities (LeFevre et al., 2009). Additionally, the results showed that home numeracy experiences accounted for 4% of the variance in math knowledge and 13% of the variance in math fluency

while controlling for demographic characteristics, vocabulary, spatial memory, and home literacy activities (LeFevre et al., 2009). The home activities contributing to children's mathematical outcomes included number skills, numeracy related games, and experience with "number-related artifacts" (such as using a calendar, money, or a watch). This study shows that incorporating numeracy related activities at home can have an impact on young children's mathematical achievement.

Skwarchuk (2009) also conducted a study assessing the frequency of opportunities for preschool children to engage with numeracy concepts in the home environment, and whether or not engaging in numeracy activities predicted math achievement. The study included 25 preschool children and their parents, and the children ranged in age from 47 to 65 months (Skwarchuk, 2009). Data were collected on student and parental demographic information, parent's mathematics experiences and attitudes, parent's opinions of numeracy activities, and the frequency of numeracy activities their preschooler had engaged in during the past week. These data were collected through surveys using a 5 or 6 point likert scale for parent math experiences, and parent opinions/ frequency of numeracy activities, respectively. The children also completed the Quantitative Concepts subtest of the Woodcock Johnson Tests of Achievement – Revised to measure children's numeracy skills. Next, parents were given educational materials that could be used to promote numeracy activities at home. Parents were instructed to spend 10-15 minutes a day with their child on a math activity over a period of 14 days. The provided activities could be used to promote math activities, or parents could use materials that they already had at home. After completing the math activity with their child, parents recorded what they did with their child and the amount of time spent on the numeracy activity in a daily journal. Finally, the parent-child dyads each attended a videotaped laboratory session where they spent 10 minutes

playing with the child's toy of choice of play-doh, safari gears, or the ball pool, and then an additional 10 minutes playing the Humpty Dumpty Game.

The researchers measured both the parent reported frequency of involvement in numeracy activities, as well as the quality of parent-child interactions during their play sessions. First, the researchers examined the parents' ratings of the importance and frequency of various numeracy activities that they did at home with their children. Two mathematics professors rated the list of activities based on the frequency of parent reported occurrence, the NCTM content standard that matched the activities (i.e., Number and Operations, Algebra, Geometry, measurement, and/ or data analysis and probability), and whether the activity was considered to be "basic" or "complex" in regard to mathematical content (Skwarchuk, 2009, p. 194). The activities were labeled as "basic" if they included activities such as printing numbers, reading numbers up to 20, reciting numerals, and counting objects (Skwarchuk, 2009, p. 194). The activities were labeled as "complex" if they included activities like adding or subtracting objects, quantity or numerical comparison, counting by twos, connecting the dots, and completing mazes (Skwarchuk, 2009, p. 194). This allowed the researchers to compare the frequency of activities done at home, and the type of activity (i.e., basic or complex) to children's mathematical achievement.

Additionally, the parent journal entries and the videotaped lab sessions were coded based on the type of numerical content, and the numerical content aligned with the content standards outlined by the National Council of Teachers of Mathematics. This was done to evaluate how much time parents actually engaged their children in mathematical activities, and to examine the mathematical content areas that parents and children engaged in. By coding the parents' diary

entries and videotaped lab sessions, the researcher was able to examine the relationship between parent-child math interactions, and children's math achievement (Skwarchuk, 2009).

The results of the parent reports showed that preschoolers numeracy scores were related to their parents experiences with and attitudes towards mathematics. Additionally, the data illustrated that experience with basic ($\beta = -.598$, $p < .048$) and complex ($\beta = .937$, $p < .013$) numeracy activities predicted unique variance in children's numeracy scores. Specifically, children who were exposed to more complex numeracy activities with their parents had higher math scores than children who were exposed to basic numeracy interactions (Skwarchuk, 2009). When parent completed diary and video taped mathematical activity sessions were reviewed, the researchers found that 25% of the parent child interaction time had no apparent mathematical activities even though parents were specifically asked to engage in numeracy activities with their children. Additionally, the researchers found that, when the parents did engage their children in numeracy activities, that the coded interactions showed they spent a greater amount of time engaging in number and operations content (37%) than algebra (11%), or statistics and probability (3%). Finally, multiple regression analyses showed that there was no relationship between quality of observed parent-child numeracy interactions and children's mathematical achievement. This could be due to the large amount of time that parents did not engage in numeracy activities during the observed sessions. However, the relationship between complex and basic parent-child numeracy interactions and children's mathematical achievement suggests that engaging children in complex numeracy activities at home may be beneficial to children's mathematical achievement.

Finally, mathematical dialogue between parents and children at an early age can have a positive impact on children's early numeracy achievement (Gunderson & Levine, 2011; Levine

et al., 2010; Suriyakham et al., 2006). Levine and colleagues (2010) conducted a longitudinal study examining how the frequency of parent number talk affected children's understanding of cardinality (Levine et al., 2010). Specifically, the researchers wanted to examine if numeracy related discussions between parents and children during early child development had an impact on the childrens' acquisition and understanding of cardinal number knowledge at 46 months of age.). Forty-four children and their parents participated in the study every four months starting when the children were 14 months until they were 30 months old. During this time, researchers visited the families in the home and videotaped 90 minutes of natural interactions between the child and their parents. Parents were told that the purpose of the study was to examine language development, and were given no further information about the types of language, specifically parent and child number talk, that would be examined (Levine et al., 2010). All speech that occurred during parent and child activities was transcribed, and cumulative parent utterances, child utterances, parent use of number words, and child use of number words were calculated. Inter-observer agreement was examined for 20% of the parent-child interactions, and the coders achieved 99% agreement on all transcriptions (Levine et al., 2010).

When the children were 46 months old, they completed the Point-to-X task to measure their understanding of cardinality. During this task, children were presented with two arrays of squares and asked to point to the array that had a given number of squares (ranging from two to six; Levine et al., 2010). The results showed that parent number talk between 14 and 30 months was significantly related to children's performance on a cardinal number knowledge assessment at 46 months. This suggests that simply talking to children and interacting with them more frequently does not increase their early numeracy skills. Instead, parents and children need to

engage in direct dialogue about numbers and math in order to enhance early numeracy skill development (Levine et al., 2010).

Collectively, the studies in this section illustrate the positive impact of parental-involvement at home on young children's early numeracy skills (Anders et al, 2012; Blevins-Knabe & Musun-Miller, 1996; Gunderson & Levine, 2011; Kleemans et al., 2012; LeFevre et al., 2009; Levine et al., 2010; Manolitsis et al., 2013; Niklas & Schneider, 2013; Skwarchuk, 2009; Skwarchuk et al., 2014; Suriyakham et al., 2006; Vandermaas-Peeler et al., 2009). By engaging children in direct and indirect numeracy related activities and discussing mathematical concepts, parents can help children develop a strong foundation in early numeracy skills.

Parent Beliefs about Early Numeracy

Given the importance of parental involvement in their children's mathematical skills at home and at school, it is important for us to be aware of parent's perceptions and beliefs about children's early numeracy skills. Previous research has suggested that parents typically see early numeracy as less important than early literacy (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012), overestimate their children's understanding of counting and cardinality (Fluck, Linnell, & Holgate, 2005), and cultural differences exist between the type and amount of numerical talk that children are exposed to (Chang et al., 2011; Hunt & Hu, 2011). Knowledge of parents' beliefs about early numeracy will help us better educate parents regarding children's mathematical skills, including the necessity of these skills to their children's long term academic achievement and how to interact with their children to best support early numeracy development.

When an examination of the current literature regarding parent's perceptions and beliefs about early mathematics was conducted, several themes emerged. First, parents typically see

early numeracy as less important than early literacy (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012). Cannon and Ginsburg (2008) conducted a study examining mother's beliefs, practices, and approaches to early literacy and early numeracy. The participants included 37 mothers of preschool children with the preschool students having a mean age of 4 years and 5 months. All of the children and families lived in the area of New York City, and all of the children attended preschool regularly. Additionally, about half of the sample was White (n = 20) with middle-to-high socioeconomic status, and half was Latina (n = 17) with low-to-middle socioeconomic status. Parents participated in three separate interview sessions and filled out surveys. The interviews and surveys examined the frequency and context of language and mathematics activities at home, and parental ideas regarding the importance of learning language, math, and daily living skills at preschool in the first and second session, respectively. In the third session, parents were asked whether they thought their children were more naturally interested in language or math, whether their children learned more about math or language naturally without being taught, and if they could only help their child learn math or language which would they select and why.

The study revealed that parents did attempt to help their children learn math concepts and to relate math knowledge to their child's interests and daily activities. They also reported, however, that they were unable to set specific mathematical goals for their children's learning because they did not have much knowledge of early mathematical skill development. Parental reports also showed that math was not practiced as frequently at home as language skills. Parents believed that math skills should be taught less in preschools than language and daily living skills, math was less interesting and required more instruction for children to learn than language, and that math was not a personal interest or strength.

Additionally, parents tend to overestimate their children's understanding of counting and cardinality (Fluck et al., 2005). A study conducted by Fluck and colleagues (2005) examined mothers beliefs about their children's cardinal understanding, and specific counting principles including object counting, mastery of the count word sequence, one to one correspondence, stable order of counting, and order irrelevance (Fluck et al., 2005). Thirty-five mothers and their children participated in the study with the children ranging in age from 40 to 51 months. The mothers completed a survey evaluating their beliefs about their children's mathematics ability and answered questions about counting principles, interest in math concepts, and cardinality. Specifically, maternal beliefs about cardinality were measured through questions looking at last word responding, or if the child repeats the last number they named instead of recounting when asked how many items they saw, and if a child would spontaneously count when asked for a specific quantity of objects (Fluck et al., 2005).

Children's cardinality, object counting, mastery of the count word sequence, one to one correspondence, stable order of counting, and order irrelevance skills were measured and compared to maternal beliefs about children's skills in these areas. Results of the study showed that while parents were fairly accurate at estimating their children's understanding of counting principles, they overestimated their children's cardinality skills (Fluck et al., 2005). Specifically, 22 parents reported their child would answer correctly on the last word response task when the objects were visible, but only one child actually gave a correct response. Similarly, 30 parents believed their child would answer correctly on the last word response task when the objects were not visible, but only seven children correctly repeated the last word on this task. When asked to give a specific number of items, 32 parents estimated that children would be able to accurately complete the task and 35 parents estimated that children would spontaneously count; however,

only eight and 17 of the children's performance matched parent expectations on these tasks, respectively. These data show that parent estimates of children's cardinal knowledge is significantly higher than how children actually perform on these tasks ($p < .01$ for all cardinality measures; Fluck et al., 2005). The results emphasize the importance of helping parents to better understand the types of interactions that promote early numeracy development in children.

Finally, cultural differences have been found regarding parents attitudes toward their child's early numeracy skills and their ability to scaffold mathematical understanding (Chang et al., 2011; Hunt & Hu, 2011). A study conducted by Chang and colleagues (2011) examined whether children who speak Mandarin Chinese and English hear similar types of number talk at home or in a naturalistic laboratory setting (Chang et al., 2011). Specifically, the researchers examined if the children hear comparable amounts of number talk, if the types of number talk in the different languages vary in ways that would impact children's numerical understanding, and if semantic differences between the languages had an impact on children's number acquisition (Chang et al., 2011). The study used transcripts in English and Mandarin from the CHILDES database that documented naturalistic interactions between children (ages 14 to 32 months) and their parents. Mandarin and English transcripts were individually matched for utterance length, child age, child gender, interaction context, and interaction length; 58 Mandarin and 68 English parent child interactions were analyzed, but some of the English interactions were combined in order to adequately match the characteristics of the Mandarin interactions.

Number instances were analyzed and operationally defined as number terms, questions about quantity, and requesting a specific quantity of objects (Chang et al., 2011). The interactions were also analyzed for differences in grammatical form (i.e. number used as a pronoun, a modifier, in a sequence, or in isolation), categories of number (i.e. inteactions with

cardinal versus ordinal numbers), and classifiers (i.e. discrete units in a set; Chang et al., 2011). The study showed that Mandarin speaking parents engaged their children in more talk about numbers than English speaking parents. Additionally the study illustrated that context in which parents referred to numbers in Mandarin was more supportive of children's understanding of cardinality than parents speaking English. While this study examined very specific populations, similar results have been found in other studies when working with American and Chinese families (Hunt & Hu, 2011) and show consistent attitudes of American parents regarding their young children's mathematics education (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012), which further emphasizes the need to teach parents about the importance of children's early numeracy skills.

Overall, this overview of studies shows that parents typically see early literacy as more important than early numeracy (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012). Additionally, parents tend to overestimate their children's understanding of counting and cardinality (Fluck et al., 2005), and the type and amount of numerical talk that children are exposed to by their parents can differ by culture (Chang et al., 2011; Hunt & Hu, 2011). This information demonstrates the importance of educating parents regarding their children's early numeracy skills. Parents need to better understand the necessity of early numeracy skills to their children's long term academic achievement and how to interact with their children to best support the development of these skills. This will enable them to more effectively assist their children in developing early numeracy skills and help prevent academic difficulties when children start school. Research also suggests that early numeracy skills are predictive of long term mathematical outcomes, so assisting parents in teaching their children early numeracy skills increases the likelihood of later mathematical success. The following

section of this chapter will review the research literature examining early numeracy interventions.

Review of Early Numeracy Interventions

In addition to the importance of parental involvement and beliefs regarding their children's math education, research also indicates the need and benefits of differentiated mathematics instruction and intervention for children within prekindergarten and kindergarten classrooms (Gersten et al., 2005). There are a variety of interventions targeting early numeracy skills at the general education, supplementary instruction, and intensive instruction levels; however, very few of these interventions focus on how parents can help their children build early numeracy skills. This section on early numeracy interventions will be broken into three major types of interventions seen in the literature: school assisted parent interventions, board game interventions, and storybook interventions. These interventions have the potential of being implemented by parents in the home environment as a tier 1 strategy.

School Assisted Parent Math Interventions

Parent directed math interventions are math activities that parents engage in with their children to promote mathematical knowledge and development. However, very little research has been done to examine how parents can enhance children's early numeracy and number sense skills. Skwarchuk (2009) found that children's numeracy scores are predicted by parental attitudes towards mathematics and suggests that parents may need guidance on how to implement numeracy related activities with their young children. The studies presented in this section provided parents with specific activities to engage in with their child. These differ from the interactions reported in the parent involvement section where researchers examined how unstructured, parent reported early numeracy interactions predicted children's achievement.

Starkey and Klein (2000) examined the effectiveness of an intervention that promoted parental involvement in children's early mathematical development and explored the results on children's early mathematical knowledge. The authors conducted two identical studies; one study had a predominantly African American population (study 1), and the other had a predominantly Latino population (study 2). The participants in study 1 and study 2 consisted of 28 and 31 mother-child dyads, respectively. The families in the study all qualified as low income based on federal guidelines and had a child (between four and five years old) enrolled in Head Start who was eligible to start public kindergarten the following school year. Participants were divided into a comparison and an intervention group, and the researchers used a pretest – posttest design for all participants. Families in the intervention group participated in eight, biweekly mathematics courses. During these classes, teachers demonstrated math activities for the whole class, and then they distributed materials to help families engage in the math activities with their child. The following topics were included in the curriculum for the family mathematics course: number concepts, arithmetic operations, logical reasoning, geometric and spatial concepts, and patterns. At the end of each class, families were allowed to borrow kits with age-appropriate mathematics activities to do with their child. Families in the comparison groups did not participate in the family math classes or have access to the mathematics activity kits (Starkey & Klein, 2000).

The researchers conducted mathematical and literacy assessments before and after implementing the intervention. Assessments used included enumeration (e.g., how many objects in an array), numerical reasoning (e.g. which container has more objects), geometric reasoning (e.g. recognizing shapes and patterns), and emergent literacy tasks (Starkey & Klein, 2000). The results of both study 1 and study 2 showed that mathematical knowledge development was

significantly higher for children in the intervention groups than the children in the comparison groups (Starkey & Klein, 2000). Additionally, children made significant growth on all areas of the mathematics knowledge assessment. It was concluded that the intervention was effective for both children who scored in the lower part of the developmental range at pretest and the children who scored in the upper range. These results show that teaching parents how to enhance their children's mathematical development and providing them with activities to do at home has a significant impact on children's mathematical achievement (Starkey & Klein, 2000).

One weakness in this study, in regards to applying this model to practice, is that is very expensive in terms of time and resources due to the amount of time professionals spent training parents and the materials included in the math activity kits provided for the parents to use with their children. Future research should examine less costly alternatives. This could include examining the effects of just having children bring home the mathematical activity kits and instructions for their parents on how to implement the activity and why the activity is important. Future research should also examine the effectiveness of this intervention with other diverse groups of students and families.

This study is the only one in the educational research that had parents partner with a school to specifically train parents how to enhance their childrens' early numeracy skills. The scarcity of research in this area could be due to the expensive nature of the study (previously discussed). However, an intervention like this one could potentially increase parental involvement both at home and at school, as well as enhance parents' abilities to help their children learn early numeracy skills. By increasing the opportunities for parental involvement and building the capacity of parents to teach their chilren, interventions similar to this one have the potential to significantly impact children's outcomes. Additionally, this type of intervention

may be particularly promising for low-income families because it gives them the opportunity to borrow early numeracy activities from their child's preschool instead of needing to purchase their own materials in addition to teaching families how to use the materials.

Game-Board Interventions

Incorporating mathematical skills into game play is one way to make learning mathematics more fun for children. Additionally, playing a game creates an environment where children can use basic math skills, as well as observe other players modeling more advanced skills when playing with older peers and adults (Vandermaas-Peeler, Ferretti, & Loving, 2012). Because of this, several studies have examined the effectiveness of playing games on children's mathematical knowledge (Hendrix & Missal, 2014; Ramani & Siegler, 2008; Ramani & Siegler, 2011; Siegler & Ramani, 2008; Siegler & Ramani, 2009; Vandermaas-Peeler et al., 2012; Whyte & Bull, 2008; Young-Loveridge, 2004).

Siegler and Ramani (2009) conducted an experiment to test whether linear number board games, circular number board games, or numerical activities had a greater impact on kids' understanding of number magnitudes (Siegler & Ramani, 2009). The study was conducted with 88, low income preschoolers who were 4-5 years old, and were recruited from Head Start centers and other child care facilities. The children participated in five, 15-20 minute sessions during a three week period. Children were randomly assigned to one of the three activities. In the number board game intervention, the children played a game that resembled a horizontal number line labeled from one to ten. The child and the examiner would take turns moving their pieces on the board, after using a spinner to determine how far to move, and say the numbers on the game board as they moved their piece. For example, if the child's piece was on space 5 and they were required to move their piece 2 spaces, then the child would say "6, 7" as they moved their piece.

Children in the circular board game group played the same game except the shape of their game board was circular. Finally, children in the numerical activities control group participated in number, oral counting, object counting, and numeral identification activities. In the oral counting measure, children were simply asked to count from one to ten. In the object counting measure, children were asked to count a row of poker chips that varied in number (ranging from one to ten) on each trial (Siegler & Ramani, 2009). Intervention activities across all conditions were administered by trained research assistants.

The researchers conducted pretest and posttest measures of children's numerical knowledge and assessed children's counting, number line estimation, numerical magnitude comparison, numeral identification, and addition skills. Most of these activities are clearly explained by their names (e.g. counting, numerical magnitude comparison, numeral identification, and addition skills), but the number line estimation task is not as clear and will be explained in more depth. On this task, children were presented with a sheet of paper that had a line drawn on it with "0" printed on the far left and "10" printed on the far right end of the line, and a random number between 1 and 9 printed above the line. The children were asked to indicate what number was above the line and where they would put it on the line. Specifically, children were asked, "If this is where 0 goes (pointing) and this is where 10 goes (pointing), where does *N* go?" (Siegler & Ramani, 2009). The results showed that playing the linear board game significantly increased children's understanding of numerical magnitudes. This reflected an increase in children's accuracy on the number line estimation, numerical magnitude comparison, and addition tasks. This suggests that playing a linear board game can help children better understand numerical relationships (Siegler & Ramani, 2009). Future studies should be

conducted to determine if parents playing linear number board games with their children have a positive impact on children's early numeracy skills.

Ramani and Siegler (2008) conducted an additional study that targeted the impact of game boards on early numeracy. The study compared the effectiveness of numerical linear board games to colorful linear board games. The researchers assessed 124 preschool children ranging in age from 4 to 5 years, and all children were enrolled in Head Start programs. The study used a pretest- posttest design, and the assessment and intervention procedures were very similar to those used in the previous study (Siegler & Ramani, 2009) with the exception of the procedures used in the colorful linear board game. Instead of having children count as they moved their piece in the colorful board game condition, children were required to say the colors of the squares (i.e. "red, blue"). Additionally there was not a numerical activities control group in this study (Ramani & Siegler, 2008).

The results of the study showed that playing linear number board games was more effective in enhancing children's numerical knowledge than playing colorful linear games. Children in the linear number board game group scored higher on all of the assessment measures at posttest than they did at pretest, and they also scored higher than the colorful board game group at posttest. The colorful board game group showed no change in performance from pretest to posttest (Ramani & Siegler, 2008). Collectively, these findings suggest that exposure to number board games, across home and school settings, can have a positive impact on children's numerical knowledge.

Finally, Vandermaas-Peeler and colleagues (2012) conducted one parent directed intervention study where they had parents engage their children in a board game, *The Ladybug Game*, which incorporates both numeracy and literacy components. Notably, this is the only

parent implemented game-board intervention study. Twenty-eight parent/child dyads participated in the study, and children were 54 months of age. The participants were randomly assigned to either the numeracy awareness group or the comparison group. The parents in the numeracy awareness group were provided with a list of strategies to help them incorporate numeracy activities into the board game, and parents were free to consult this list as they played with their children. The comparison group did not receive this list, and were not given any indication that the study was focusing on numeracy. The children and parents participated in three sessions of game play, once in a research laboratory and twice in the home environment, and they audio recorded each of these three interactions between parent and child playing the game. The parent/child interactions were then coded by the researchers for numeracy related interactions (e.g. questioning that encouraged a child to use a mathematical skill or modeling a skill). These coded interactions were then used to determine the total number of correct and incorrect math responses during game play.

The study found that parents provided with suggested numeracy strategies used twice as many basic number (i.e. counting and number recognition) and advanced number (i.e. addition and subtraction) activities during the game than the parents in the comparison group (Vandermaas-Peeler et al., 2012). Additionally, children in the numeracy awareness group had higher correct response rates for addition and subtraction problems, counting, number recognition, and number comparison than comparison group children during the coded game playing sessions. Children in the numeracy group also showed an increase in the total number of correct answers during the game playing sessions from the first to third session. Finally, parents in the numeracy awareness group provided more guidance for numeracy activities than the comparison group. The authors note that the increased guidance received by the numeracy

awareness group and the higher proportion of correct responses to advanced number activities suggests that these activities extended the children's zone of proximal development.

This study suggests that providing parents with numeracy activities to use with their children can enhance children's mathematical skills. However, further research is needed to confirm these findings with more diverse populations. Additionally, future research should examine how parent/child interactions playing The Ladybug Game, or other early numeracy games, impact children's mathematical performance on standardized numeracy measures. Longitudinal studies could also examine the long-term, educational impacts of this type of intervention. Finally, this study illustrates that game-board interventions could potentially improve children's early numeracy skills when they are implemented by the children's parents.

Storybook Interventions

Mathematical skills can also be incorporated while reading storybooks to make learning mathematics more fun for children. Research suggests that shared book reading between children and adults allows children to experience vocabulary and topics that they do not typically encounter during their daily experiences (Fletcher & Reese, 2005). Additionally, there is support to suggest that is a beneficial activity during early childhood (National Early Literacy Panel, 2008), and that number and math talk between parents and children is beneficial to children's early numeracy development (Levine et al., 2010). Finally, parents often think of children's early literacy skills as more important than early numeracy skills (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012), which may make teaching early numeracy skills through reading a more socially valid option for parents. Several studies have examined the effectiveness of reading books on children's mathematical knowledge (Anderson et al., 2004;

Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013).

A study by Anderson and colleagues (2005) conducted an exploratory, qualitative study to assess parent-child interactions while they read two storybooks including math concepts (Anderson et al., 2005). Specifically, the researchers wanted to determine if parents and children would engage in math related discussions while reading books together. Thirty-nine parents and children participated in the study (Anderson et al., 2005). Children were four years old and recruited from day care centers in Canada. Participants were socioeconomically, culturally, and linguistically diverse including Danish, Mandarin, Slovene, Cantonese, and English speaking participants; however, all of the children attended day cares where English was the primary language of instruction, and parents reported that they typically spoke with and read to their children in English (Anderson et al., 2005). Parents and children read the books *Mr. McMouse* and *Swimmy* together, either at home or at the day care center, and the researchers videotaped each dyad reading these stories. The order in which parents and children read the stories was counterbalanced across participants (Anderson et al., 2005).

The researchers transcribed all discussions during the storybook reading and the discussions were divided into conversational turns between the parent-child dyad (Anderson et al., 2005). The conversational turns were examined for mathematical content, and math related discussion was coded into one of three categories: (1) size (e.g., a big fish), (2) number (e.g., five mice), and (3) shape (e.g., a circle; Anderson et al., 2005). The coded transcriptions were then examined for themes that occurred across families. The results showed that there was variability in the amount of math related discussion across families ranging from 0 to 21 conversational turns related to math. Nine families engaged in more than half of the math related discussion

observed, while some families had little to no math related discussion (Anderson et al., 2005). Additionally, there was three times as much math related discourse in while parent-child dyads read Swimmy (n = 180 total conversational turns) than when they read Mr. McMouse (n = 53 total conversational turns; Anderson et al., 2005). Finally, the coding revealed that the families spent more time discussing size (n = 149 total conversational turns) than number (n = 74 total conversational turns) or shape (n = 10 total conversational turns; Anderson et al., 2005).

Overall, this study shows that parents and child can use storybook reading as a method for engaging in mathematical discussions. However, there was great variability in the amount of math related speech between families. Additional studies should be done to examine the reasons for the great variability in math discussions between families. Future research should also examine techniques to encourage families to engage in math dialogue between parents and children while reading storybooks.

A study conducted by Hojnoski and colleagues (2014) extended the research on storybook reading by examining the effectiveness of storybook reading on early numeracy skills by helping parents incorporate math concepts and vocabulary into reading with their children (Hojnoski et al., 2014). Six parent-child dyads participated in the study with children ranging in age from 40 to 68 months. The researchers used a multiple baseline design, and they yoked dyads across 3 baselines so that all six dyads could participate. During baseline and intervention phases, parents were given three books each week, and asked to audio record while they read the books to their child (Hojnoski et al., 2014). While parents were allowed to read the books multiple times, they only recorded the initial reading session for each book. Parents received training from the researchers at the beginning of the baseline and intervention phases of the study. Training at the baseline phase of the study included gathering demographic information,

parent consent, providing the parents with materials, and showing them how to use the audio recorder. In addition to receiving the storybooks, parents also received a reading guide with a brief summary of each book (Hojnoski et al., 2014). Books during the baseline phase included both math related and non-math related storybooks to ensure that any increase in children's early numeracy skills during the intervention phase was not due to the introduction of math related storybooks. Baseline included three to nine reading sessions for each family depending on their baseline assignment (Hojnoski et al., 2014).

Parents received additional training at the beginning of the intervention phase to show them how to engage in math talk while reading to their child (Hojnoski et al., 2014). This training session provided information regarding the domains of early numeracy, and common preschool mathematics vocabulary from mathematics curricula (Hojnoski et al., 2014). Parents also received instruction in dialogic reading. This was organized around three key concepts including asking children questions, providing feedback, and matching parental reading style to the children's current level of ability (Hojnoski et al., 2014). Specifically, parents were taught how dialogic reading prompts could be used in a mathematical context (Hojnoski et al., 2014). Lastly, parents received materials and instructions for implementing the intervention. The researchers provided parents with three books each week to read with their child, and this included two intervention books and one generalization book (Hojnoski et al., 2014). All three books included a reading guide, however, the intervention book reading guides provided ideas and recommendations for discussing math concepts throughout the story whereas the generalization book only included a plot summary. Researchers gave the parents a designated order to read the books with the two intervention books first followed by the generalization book.

This assessed whether the parents could incorporate math concepts into the generalization book based on the reading guides from the previous intervention books (Hojnoski et al., 2014).

The researchers used parent and child math talk as the outcome measure for this study. They transcribed and coded all of the audio recordings for speech that occurred in addition to the story text. The coding examined math and non-math related speech, for both the parent and child, in order to calculate the percent of total math talk for each reading session. Study results indicated that the mean percentage and frequency of math talk increased for both children and parents from the baseline to intervention phases. Further statistical analysis, using trend and percentage of non-overlapping data (PND), revealed that the increases were not consistent or statistically significant (Hojnoski et al., 2014). When data from the individual parent-child dyads was examined, the results illustrated that three dyads showed a positive change from the intervention and three did not (Hojnoski et al., 2014). Generalization probes were also examined to determine if the parents continued to use math talk when they were not provided with a reading guide. The analyses showed that the frequency of math talk during the generalization stories was greater than the math talk during baseline (Hojnoski et al., 2014). Additionally, parents used fewer math phrases during the generalization stories than the intervention stories, but the proportion of math talk to non-math talk indicated that most of the speech was math related (Hojnoski et al., 2014).

While this study shows promise for using storybooks as a tool to promote early numeracy skills, the results are inconclusive. Future research should replicate this study to develop a better understanding of the efficacy of this intervention. Additionally, future research could include early numeracy and literacy curriculum based measures to directly examine the impact of the

intervention on children's academic achievement not only on numeracy but on literacy concepts as well.

Collectively, the summarized intervention studies show that children's early numeracy skill development can be enhanced through parent directed, board game, and storybook reading interventions. Additional research needs to be done in the area of parent directed early numeracy interventions to determine specific ways in which parents can work with their children to help them develop a strong foundation in early numeracy skills. Based on parental beliefs regarding the importance of early literacy and early numeracy, creating an intervention that has the potential to increase both early numeracy and literacy skills would be particularly beneficial. The study done by Hojnoski and colleagues (2014) shows that reading storybooks with young children has the potential to increase both early numeracy and literacy skills because of the connections between the increase in mathematical dialogue and the use of modified dialogic reading. When employed separately, both dialogic reading and math dialogue have been shown to increase children's academic skills in early literacy and numeracy, respectively, which makes an intervention that includes both of these techniques promising for improving children's academic outcomes. In addition, by doing an intervention at the preschool level, the intervention has the potential to prevent academic difficulties in the areas of numeracy and literacy once the child starts kindergarten. This is important since a strong foundation in early numeracy skills has the potential to help students obtain higher levels of achievement later in life.

Purpose of the Present Study

Preschool and kindergarten students with strong early numeracy skills are more likely to attain higher levels of mathematical and reading achievement later in their education (Duncan, et. al., 2007). Additionally, early numeracy interventions have the potential of helping students

enhance their immediate and long term math skills. Therefore, it is necessary to ensure that children receive high quality instruction and interventions in early numeracy in order to develop a strong foundation of mathematical skills. Research has illustrated that board games (Hendrix & Missal, 2014; Ramani & Siegler, 2008; Ramani & Siegler, 2011; Siegler & Ramani, 2008; Siegler & Ramani, 2009; Vandermaas-Peeler et al., 2012; Whyte & Bull, 2008; Young-Loveridge, 2004), storybooks (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013), and parent directed interventions (Anderson et al., 2004; Anderson et al., 2005; Hendrix & Missal, 2014; Hojnoski et al., 2014; Starkey & Klein, 2000; Vandermaas-Peeler et al., 2012) can all be used to enhance children's early numeracy skills. Parent directed interventions may be especially promising given the importance of parental involvement in children's early numeracy achievement. However, little research has been done to directly examine the effectiveness of shared storybook reading between parents and children to increase children's early numeracy skills. This study tested the efficacy of shared parent-child storybook reading in increasing children's early numeracy skills among preschool children aged four to five. The results of this study added to the existing literature by examining not only parent-child math discussions while reading storybooks but also children's early numeracy achievement outcomes.

Research also indicates that parent involvement in the home (Anders et al, 2012; Blevins-Knabe & Musun-Miller, 1996; Kleemans et al., 2012; LeFevre et al., 2009; Levine et al., 2010; Manolitsis et al., 2013; Niklas & Schneider, 2013; Skwarchuk, 2009; Skwarchuk et al., 2014;Vandermaas-Peeler et al., 2009) and school (Blevins-Knabe & Musun-Miller, 1996; Fan & Chen, 2001; Galindo & Sheldon, 2012; Hill & Taylor, 2004; Kleemans et al., 2012; LeFevre et

al., 2009; Miedel & Reynolds, 1999; Powell et al., 2010; Sheldon & Epstein, 2005; Wade, 2004; Yap & Enoki, 1995) environments is important for children's early numeracy skill development. However, parents often prioritize early literacy skills over early numeracy skills, and overestimate children's competency in early mathematics (Cannon & Ginsburg, 2008; Fluck et al., 2005; Ramani et al., 2011; Sonnenschein et al., 2012). Consequently, training parents to focus on early numeracy skills while reading storybooks to their children could lead to an increased amount of parent-child early numeracy interactions. Additionally, if reading mathematical storybooks increases children's early numeracy and early literacy skills, parents may be more willing to implement shared storybook interventions with their children. This study examined children's early numeracy and literacy outcomes after training parents to include early numeracy concepts into shared storybook reading with their children.

CHAPTER THREE: RESEARCH METHODS

This chapter will discuss the research methods of the study. First, the study participants will be described. The participants section will include a discussion of participant characteristics, inclusion/exclusion criteria, risks to participants, and protection of human subjects. Next, the study procedures, research design, setting, selected intervention materials, and outcome measures used in the study are presented. Finally, the chapter will close with a review of the data analyses that were used to answer the study's research questions, as well as the ethical considerations and limitations of the study.

Participants

Participants included four parent-child dyads with children ranging in age from four to five years. According to the *What Works Clearinghouse* (WWC) criteria for experimental control, researchers should attempt to demonstrate at least three treatment effects at three different points in time (Kratochwill et al., 2010). The selected sample size allowed for 4 effects to help ensure that these criteria were met by accounting for possible attrition.

Inclusion and Exclusion Criteria

To be included in this study, children were required to be attending Voluntary Pre-Kindergarten (VPK) in the participating school district. To be enrolled in VPK, the families must be Florida residents, and children must be between the ages of four and five years. Children with intellectual disabilities, developmental disabilities, language impairments, or severe physical impairments (such as deafness or blindness) were not included in the

study. Additionally, both parents and children had to be fluent in English, and the parent needed to consent to participate and implement the reading intervention. These data were collected through parent report to determine if students met the inclusion criteria necessary to participate in the study. The interview questions that were used to determine if parents and children meet the inclusion criteria are located in Appendix E. Demographic information for the parents and children participating in the study are provided in Table 2. It should be noted that two of the participants marked more than one ethnicity when filling out the demographic questionnaire. All the ethnicities noted by parents are included in the table below.

Table 2

Participating Parent and Child Demographic Information

Variable	Parent	Child
Relation to the Child		
Biological Parent	*3*	
Biological Relative	*1*	
Gender		
Male		*2*
Female	*4*	*2*
Child's Age		
Four Years		
Five Years		*4*
Ethnicity		
Hispanic	*2*	*2*
Asian/Pacific Islander		*2*
Caucasion/ White	*2*	*2*
African American		*1*
Marital Status		
Married	*2*	
Single	*1*	
Divorced	*1*	
Highest Level of Education		
High School	*3*	
Two Year College Degree	*1*	

Participant Attrition

Four parent-child dyads were initially recruited to participate in the study. This sample size was chosen to maximize the likelihood of at least three participants completing the study, which corresponds with the What Works Clearinghouse (WWC) criteria for single case designs. The WWC criteria indicates that there must be evidence of at least three experimental effects at three different points in time (Kratochwill et al., 2010). One participant dropped out of the study after completing four weeks in baseline and one week in intervention. The participant was not able to be contacted, and, therefore, the reason they dropped out of the study is unknown. Because the dyad was able to start the intervention, their data will be included in the visual and multi-level modeling analyses.

Risks and Costs to Participants

The risks and costs to participate in this study were minimal. Parents may have experienced increased stress due to the extra time required to participate in the study. Participants also incurred travel costs for biweekly meetings with the primary investigator for trainings and exchange of materials. Time and location of meetings were scheduled based on parent availability and location preferences and travel costs were not reimbursed.

Participant Compensation

Parent-child dyads were able to choose one children's book included in the study to keep each week, and received three additional books at the end of the study (for a total of 10 books). For participants who dropped out of the study early they received one storybook for every week that they participated. Additionally, children were given a small prize (e.g., stickers, erasers, pencils, etc.) after meeting with the examiner and completing assessments each week.

Procedures

The following sections will describe the study design, recruitment procedures, setting, baseline procedures, intervention procedures, researcher training procedures, and the study materials.

Study Design

The current study was conducted using a concurrent multiple baseline single-case design across participants. Multiple baseline design employs experimental control by staggering the baseline and intervention phases of the study over time. By starting the intervention for one student, while the remainder of the students stay in the baseline phase, one would expect to see a change in performance for the student receiving treatment but not for the students in baseline. This pattern suggests that the change in performance is likely due to the intervention and not extraneous variables. In addition to its methodological rigor, a multiple baseline design is the most functionally appropriate method for this study because students will gain knowledge and skills once the intervention begins, which makes a design requiring a return to baseline illogical. Finally, a multiple baseline design can be used to conduct statistical analyses that measure the effectiveness of treatment for both individual students and across students.

During the study, parent-child dyads were randomly assigned to one of three baseline conditions with two dyads randomly paired to each baseline. Yoking dyads across three baseline conditions allowed for the inclusion of six participants in the study, but did not require any dyad to remain in baseline for an extended period of time. The baseline phase of the study lasted from two to six weeks. Progress monitoring data during baseline and intervention phases were collected two times a week. Families read three books per week during the baseline and intervention phases; therefore, baseline included six to 12 reading sessions for each family

depending on their baseline assignment. Table 3 provides the schedule used for participants during the baseline phase of the study.

Table 3

Baseline Schedule for Participants

Participants	Weeks in Baseline	Baseline Reading Sessions	Baseline Data points
Dyad 1 & 4	2	6	5
Dyad 2	3	9	7
Dyad 3	4	12	9

Following baseline, each dyad participated in nine to 15 additional reading sessions during the intervention phase depending on when they entered the intervention phase. Similar to the baseline phase, the intervention phase of the study was divided into three reading sessions per week, and progress-monitoring data were collected twice a week. Thus the intervention phase of the study ranged from four to eight weeks, and the total time in the study for all families was 10 weeks. Baseline and intervention study procedures were designed to be similar to those used in Hojonoski and colleagues (2014) research, allowing for the comparison of results between studies. Table 4 provides an example schedule for participants during the intervention phase of the study. Additionally, Figure 1 provides a visual display of the multiple baseline design.

Table 4

Intervention Schedule for Participants

Participants	Weeks in Intervention	Intervention Reading Sessions	Intervention Data points
Dyad 1 & 4	5	15	10
Dyad 2	4	12	8
Dyad 3	3	9	6

Ethical Considerations

The University of South Florida Division of Research Integrity and Compliance

Institutional Review Board (IRB) reviewed and approved the current study before interaction with participants or data collection began. A proposal for the study was also submitted to the Office for Accountability, Research and Measurement in Pasco County School District, and the principals at all participating schools agreed to allow participant recruitment to occur.

Recruitment Procedures

Children and their parents were recruited through VPK preschool classrooms in Pasco County School District. Because participant recruitment occurred during the summertime, families were recruited from two schools that had VPK classes during the summertime. After the Office of Accountability, Research, and Measurement in Pasco County approved the study, teachers in the selected VPK classrooms sent home letters to all students in their classrooms describing the study. Five interested parents signed and returned the letters to the students' preschool teachers. The forms were then collected on a predetermined date, and parents were contacted (by their preferred method of communication) to schedule a screening to determine if they met the inclusion criteria (described previously). Once parent-child dyads who met the inclusion criteria were identified, the researcher scheduled the initial training session to be held prior to the start of baseline. Out of the five parents that returned the recruitment letters, four completed the initial screening. The fifth parent that returned the recruitment letter could not be reached. All four parents who completed the initial screening interview qualified and agreed to participate in the study. The recruitment materials are located in Appendix A.

Informed Consent Procedures

Informed consent was obtained at the beginning of the initial training meeting between parents and the primary investigator. Each parent met individually with the primary investigator and/or trained members of the research team at a time and location convenient to the parent.

During this meeting, the primary investigator reviewed the consent form with the parents, and provided them an opportunity to ask questions. Once all questions had been answered, parents were told that if they were still interested in participating in the study that they must sign the consent form and keep a copy for their records. Additionally, they were given the contact information of the primary investigator and told that if they have any follow-up questions about the study or their rights as participants that they may contact the primary investigator at any time.

In addition to consenting to participate in the study, parents were asked to sign a separate consent to allow their student to be audio recorded during the assessment sessions twice a week. Consent to audio record assessment sessions was obtained during the last two weeks of the study due to delays in receiving IRB approval for this change in procedures. Additionally, consent was only obtained for two students because one student had already completed the study by the time IRB approval was received. This allowed the primary investigator to listen to student responses on the vocabulary measures to ensure accurate transcription and scoring of student responses..

Setting

Parents completed all reading activities with their children during the baseline and intervention phases of the study, and the reading sessions took place in the families' homes. Parents were provided with materials and instructions so they could conduct the reading sessions themselves in the home environment. When meeting with the families to provide training or to check in, the primary investigator collaborated with the children's parents to choose a location that was convenient for the family (e.g., the child's school, public library, family home). The primary investigator or a member of the research team met with each family twice a week to administer progress monitoring assessments to the students, answer any parent questions, and problem-solve any difficulties the parents experienced in implementing the intervention.

Baseline Procedures

During the baseline phase of the intervention, the primary investigator had an initial training meeting with the individual parents to gather demographic information, provide the parents with the storybooks they were reading that week, and to show them how to use the audio recorder. Initial progress monitoring data were also collected at this first meeting. Parents received three storybooks and were instructed to read the stories with their child as they normally would. They were asked to audio record the first time they read each book with their child. While parents were welcome to read the books multiple times with their child, they were only asked to record the initial reading session for each book. In addition to receiving the storybooks, parents also received a Book Reading Survey to fill out indicating when they first read each book with their child, if they read the book more than once, and reminding them to audio record their reading sessions. A sample of this survey can be found in Appendix F. Books during the baseline phase were math related storybooks to ensure that any increase in children's early numeracy skills during the intervention phase was not due to the introduction of math related storybooks.

Intervention Procedures

At the beginning of the intervention phase, parents participated in a training session with the primary investigator to show them how to engage in math talk while reading to their child. The training was scheduled during one of the two weekly progress monitoring assessment sessions with each family individually. This training session took about half an hour, and the majority of the instruction was focused on teaching parents dialogic reading techniques. Specifically, parents were taught how dialogic reading prompts can be used in a mathematical context, and were given the chance to watch the primary investigator complete one of the

activities with their child. Parents were then allowed to role-play using these techniques with their child. This training was organized around three key concepts including asking children questions to engage them in the text, providing feedback based on their child's answers, and matching their reading style with their child's ability levels. Parents were informed that the training session would make the assessment session a little bit longer than normal before the session occurred, so they were able to bring activities for their child to engage in during the didactic portion of the training. The primary investigator also brought smalls toys and activities that the children could play with while their parents engaged in the training sessions. A brief portion of the training also included information regarding the domains of early numeracy (i.e., numbering, relations, and arithmetic operations) and preschool mathematics vocabulary from commonly used math curricula. Because research shows that parents typically see early numeracy as less important than early literacy (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012), this part of the training provided parents with a brief context of the intervention, and helped them better understand the importance of early numeracy activities. Lastly, parents received materials and instructions for implementing the intervention. Parents were provided with three books each week to read with their child, and three reading guides that provided ideas and recommendations for discussing math concepts throughout the stories.

Researcher Training Procedures

Research team members assisted the primary investigator with data collection and intervention implementation. All research assistants were current students at the University of South Florida enrolled in the School Psychology graduate program. Research assistants were enrolled in at least their second semester of the graduate training program, and had completed at least one Psychoeducational Assessment course where they learned how to conduct curriculum

based assessment and build rapport with students. Additionally, all research assistants had completed the Institutional Review Board (IRB) training on conducting research with human participants.

In addition to the initial requirements listed above, the research assistants and the primary investigator all received training in the measures included in this study. Specifically, the assessment manuals for the early numeracy and early literacy manuals were thoroughly reviewed by all individuals. Next, the administration and scoring procedures were reviewed by the research team members and the primary investigator in pairs of two or three people. The research assistants and primary investigator had the opportunity to role play the administration and scoring of the assessments with each other, and then discussed questions about the assessments as a group. Any questions that were not resolved by the primary investigator and the research team members were sent to the major professor on this study for additional supervision and guidance. The primary investigator and all research assistants were supervised during this process by the major professor on this study.

Materials

Throughout both the baseline and intervention phases of the study, the primary investigator met with the parents and children twice a week to monitor student progress, answer questions, provide the parent with additional materials, and to collect audio recordings from the reading sessions. Materials included children's storybooks focusing on math and non-math related topics, digital audio recorders, reading guides for each book, and the early numeracy and early literacy measures.

Storybook Selection Procedures. Storybooks used in the baseline and intervention phases were identified through two methods. Storybooks used by Hojnoski and colleagues

(2014) that focused on numerical concepts (e.g., counting, ordinality, simple addition and subtraction concepts, etc) were selected to be included in the study. Reading guides created by Hojnoski and colleagues (2014) were used for some of the books obtained from the study, and used as models to create reading guides for stories where reading guides were not previously created. In order to identify additional storybooks, a teaching resource (i.e., Janes & Strong, 2014), focused on helping teachers explain early numeracy concepts through book reading, was examined and the suggested mathematical storybooks from this resource were selected. Books needed to be developmentally appropriate and to focus on numerical concepts in order to be included in the study. Once the books were selected, randomization was used to place the books in a random order. All of the selected storybooks focused on mathematical concepts, in both phases of the study, to ensure that intervention effects were due to the mathematical dialogue between parents and children, and not due to the introduction of mathematical stories; however, during the baseline phase participants did not receive reading guides. Additionally, the order of the books remained the same for all participants. Appendix J has the list of storybooks that will be used in the study.

Storybook Reading Guides. Storybook reading guides were a tool utilized in a similar study conducted by Hojnoski and colleagues (2014). The reading guides used in the previous study were reviewed, and similar techniques were used to create reading guides for the current study. Reading guides include a list of recommended dialogic reading questions for parents to ask while reading the storybooks with their child, and a list of additional activities for the parent-child dyads to engage in after reading the book to help reinforce the mathematical concepts in the book. Appendix K has the storybook reading guides that will be used in this study.

Measures

The following sections outline the measures that will be used in the study. First, the preliminary measures (i.e., parent screening interview and the demographic questionnaire) will be described. The outcome measures used to assess the dependent variables are also discussed. These measures include early numeracy achievement, mathematical dialogue during storybook reading, early literacy achievement, intervention integrity, and social validity.

Screening interview

Once recruitment flyers were returned from the parents wishing to participate in the study, a screening interview took place via telephone to ensure that the parents and child met the necessary inclusion criteria. If the parent and child met inclusion criteria, the primary investigator scheduled the baseline training sessions with the parents. A copy of the screening questionnaire is presented in Appendix E.

Demographic questionnaire

A demographic questionnaire was completed by each parent at the beginning of the study. Parents were asked to provide demographic data, including age, race/ethnicity, marital status, and highest level of education obtained. Additionally, parents provided demographic data for their child including the child's name, date of birth, and race/ethnicity. A copy of the demographic questionnaire is presented in Appendix C.

Early Numeracy

Subtests from the *eNumeracy: Early Math Assessments* (previously known as the *Early Numeracy Skill Indicators* or the *ENSI*; Methe, Iodice, Fortunato, Ray-Silva, Nelson, & Christ, 2014) were used in this study to measure students' growth in early numeracy achievement over time. Assessments were given to students twice a week during the baseline and intervention

phases of the study, and the subtests given included: Counting Arrays, Matching Quantities to Numerals, Ordinal Position, Partitioning Equal Quantities, and Number Recognition. All of the assessments were designed for preschool children except for the Ordinal Position measure, which was created for kindergarten children. Based on developmental research, however, understanding ordinal position is a skill that develops around four and five years of age (Clements & Sarama, 2014), and there were no additional measures that assess Ordinal Position in preschool children. Therefore the kindergarten *eNumeracy Early Math Assessment* subtest of Ordinal Position was used in this study.

Previous studies have examined the reliability and validity of measures similar to the ones administered (Methe, Hintze, & Floyd, 2008; Methe, Begeny, & Leary, 2011); however, the primary author on these measures has noted that the measures have been recently updated, and there were no current reliability and validity data available at the time of this study. Table 5 provides a summary of the reliability and validity data from previous studies for Matching Quantities to Numerals, Ordinal Position, Partitioning Equal Quantities, and Number Recognition. No data were available on the reliability and validity for the Counting Arrays measure. The reliability and validity data reported in Table 5 were collected from previous versions of the kindergarten assessment form. The current versions of the measure, however, had both kindergarten and preschool forms available and the current study used the preschool forms for all early numeracy concepts except Ordinal Position (which was measured with the kindergarten forms).

Table 5

eNumeracy Reliability/Validity Data

Name of Measure (Study)	*Subtests*	*Reliability*	*Validity*
Early Numeracy Skill Indicators (Methe, Hintze, & Floyd, 2008)	-Match Quantity Fluency (MQF) -Number Recognition Fluency (NRF) -Ordinal Position Fluency (OPF)	**Test-Retest**: NRF= .98 MQF= .74 OPF= .81	**(Criterion [Fall/ Winter]) TEMA-3**: NRF= .72/ .64 MQF= .55/ .20 OPF= .63/ .60 **Predictive Validity with Spring Criterion Measures:** NRF= .70 MQF= .41 OPF= .58
Early Numeracy Skill Indicators (Methe, Begeny, & Leary, 2011)	-Match Quantity (MQ) -Equal Partitioning (EP) -Ordinality to Five (OP)	**Test-Retest/ Mean KR20:** MQ= .75/ .73 EP= .83/ .84 OP= .90/ .88 **Alternate Form Reliability (Range):** EP= .78-.81 OP= .61-.70 MQ= .42-.45	**Concurrent Validity:** **WJ-III Calculation Subtest:** MQ = .05-.15 EP = .22-.38 OP = .29-.64 **WJ-III Applied Problems Subtest:** MQ = .11.29 EP = .41-.62 OP = .51-.58 **WJ-III Math Fluency Subtest:** MQ = .18-.41 EP = .29-.40 OP = .22-.36 **WJ-III Broad Math Composite:** MQ = .09-.29 EP = .29-.45 OP = .43-.61 **WJ-III Brief Math Composite:** MQ = .03-.26 EP = .22-.52 OP = .43-.63

Note. MQF = Match Quantity Fluency; NRF = Number Recognition fluency; OPF = Ordinal Position Fluency; MQ = Match Quantity; EP = Equal Partitioning; OP = Ordinality to Five; TEMA-3 = Test of Early Mathematics Achievement, Third Edition; WJ-III = Woodcock-Johnson III Tests of Achievement, Normative Update.

Counting Arrays. The Counting Arrays subtest is a timed assessment where students were presented with arrays of dots. Students were asked to count the dots aloud, and then to

state the total number of dots counted. There were six, separate arrays of dots for students to count, and they could receive points for sequencing (correct order of numbers), tracking (counting each dot only once), one-to-one correspondence (each dot represents only one number), and cardinality (correctly stating how many total dots were counted). If a student counted silently but provided a correct response for cardinality, then they were also given points for sequencing, tracking, and one-to-one correspondence. This was based on the assumption that seeking, tracking, and one-to-one correspondence must be correct if the student is able to give a correct response for cardinality. While all four of these variables were assessed, cardinality is the primary skill of interest. Additionally, the total time elapsed for all six arrays was calculated.

Matching Quantities to Numerals. The Matching Quantities to Numerals assessment is a timed test that required students to match an array of dots with its numeric representation. The student was presented with one array of dots and four numeral choices, and asked to point to the number that matches the array of dots. The assessment consists of eight items, and the total number of correct matches and the total time was recorded. If the student hesitated for three seconds on any item, it was marked as incorrect and the next item is presented. Additionally, the student needed to point to the written number, not just say how many dots there are, to receive credit for correct responses.

Ordinal Position. The Ordinal Position assessment is a timed test that required students to identify and express ordinal numbers when presented with a row of objects. For example, the students were presented with a row of objects and asked "What place is the pencil in?" or "Point to the picture in 3rd place." This assessed how well the children understood that numbers can represent position as well as quantity. The Ordinal Position measure consists of ten items, and

the total time was recorded. If the student hesitated for three seconds on any item, it was marked as incorrect and the next item is presented.

Partitioning Equal Quantities. The Partitioning Equal Quantities assessment is a timed test that looked at students' abilities to identify equal sets. Specifically, this assessment required children to view an array of objects and to divide them equally among two people, or to view arrays of objects divided between two people and decide if their arrays contain equal amounts. If the student hesitated for five seconds on any item, it was marked as incorrect and the next item was presented. This measure contained eight items, and the total number of items correct and the total time were recorded.

Number Recognition. The Number Recognition assessment is a timed test that examined student accuracy and fluency in naming numbers. The students were presented with a list of numbers from zero to twenty and asked to name each number. If the students hesitated for three seconds on any number, it was marked as incorrect and the student was asked to name the next number. Once the student named all of the numbers presented, the total time and numbers named correctly were recorded.

Parent-Child Math Dialogue

Reading sessions between parents and children were recorded to enable mathematical dialogue to be measured. One recording from the baseline phase and one recording from the intervention phase were transcribed for each parent/ child dyad to examine if there was an increase in mathematical dialogue between phases. Specifically, one randomly selected recording was transcribed during the second week of the baseline phase and another was transcribed during the seventh week of the intervention phase for each participant. Although this

only provided a sample of mathematical dialogue from each phase of the study, previous studies have used similar methods to measure mathematical dialogue (Boonen et al., 2011; Klibanoff et al., 2006;). Transcriptions only included extra-textual dialogue**,** and text from the storybooks was not transcribed or coded. The coding scheme was developed based on the methods used in Hojnoski and colleagues (2014) research. Total mathematical dialogue was coded based on utterances, which are defined as sentences or phrases spoken by either the parent or child during the reading session. Utterances were identified in the transcriptions through punctuation or a change in speaker after a sentence or phrase. Once the utterances were identified, they were categorized as containing math or non-math related speech, and the percent of total math talk, for both parents and children, during each reading session was calculated.

Early Literacy

The Preschool Early Literacy Indicators (PELI; Aguayo, Kaminski, & Abbott, 2014) were used in this study to measure students' growth in early literacy achievement over time. The PELI has two types of assessments: the PELI books and the PELI Quick Check measures. The PELI books include four subtests: Alphabet Knowledge, Comprehension, Phonological Awareness, and Vocab/ Oral Language. Similarly the PELI Quick Check measures have subtests for Alphabet Knowledge, Phonological Awareness, and Vocab/ Oral Language. Two of the PELI books were administered as pre-test and post-test measures (during baseline and intervention phases, respectively), and the PELI Quick Check measures for Phonological Awareness and Vocab/ Oral Language were given twice a week during the baseline and intervention phases of the study. Table 6 provides a summary of the reliability and validity data for the PELI books; however, the authors indicated that no data were available on the reliability and validity of the PELI Quick Check measures.

Table 6

PELI Reliability/ Validity Data

Name of Measure (Study)	*Grade, Age*	*Administration Time*	*Validity*	*Reliability*
Preschool Early Literacy Indicators (PELI; Kaminski, Abbott, Bravo-Aguayo, Latimer, & Good, 2014)	Pre-K, ages 3-6	11 minutes to administer entire book-format measure Measures Include: - Alphabet Knowledge -Comprehension -Phonological Awareness - Vocab/ oral language	**Concurrent Validity:** **CELF Total Score:** - PELI Comprehension = .69 - PELI Vocab/ oral language = .68 - PELI Phonemic Awareness = .69 **PPVT:** - PELI Comprehension = .52 - PELI Vocab/ oral language = .54 **TOPEL Print Knowledge:** - PELI Alphabet Knowledge = .75 **TOPEL Phonological Awareness Subtest:** -PELI Phonemic Awareness = .24 **IGDIs Phonological Awareness Subtest:** - PELI Phonemic Awareness = .28-.38 **IGDIs Vocabulary Subtest:** - PELI Comprehension = .43 - .54 - PELI Vocab/ Oral Language = .40 - .58 **DIBELS Letter Naming Fluency Test:** -PELI Alphabet Knowledge = .84	**Inter-rater Reliability:** .91 - .99 **Alternate Form Reliability:** .89 - .94

Note: PELI = Preschool Early Literacy Indicators; CELF = Clinical Evaluation of Language Fundamentals; PPVT = Peabody Picture Vocabulary Test; TOPEL = Test of Preschool Early Literacy; IGDIs = Individual Growth and Development Indicators; DIBELS = Dynamic Indicators of Basic Early Literacy Skills.

Alphabet Knowledge. The Alphabet Knowledge subtest of the PELI books assesses a student's ability to identify upper – and lower-case letters. An array of letters was presented to the child on a page, and the child was asked to point to and name all of the letters he/ she recognized. If a child did not name a specific letter, the examiner pointed to that letter and asked the child to name it. If the child provided the letter sound instead of the letter name, they are reminded to name the letters, but they are not penalized for giving the correct letter sound. The

total number of correct letters identified was calculated. This subtest was discontinued if the child did not name any letters and responded incorrectly to the first three letters prompted. The Alphabet Knowledge subtest for the PELI Quick Checks was not administered because alphabet knowledge is not a skill that was expected to increase based on the intervention. Because of this, the Alphabet Knowledge subtest was only given at pre- and post-test when the PELI books were administered.

Comprehension. The Comprehension subtest of the PELI books assesses a student's ability to understand what is happening in the story. The three types of questions included inference and prediction questions, recall questions, and cloze text passages that the student completed verbally. For the inference and prediction questions, and the recall questions students received two points for an answer that showed he/ she accurately understood the story, one point for an answer that was plausible but not completely related to the question (e.g., naming an item from the story but not the target item), and zero points for an answer that was clearly incorrect. For the cloze text passages, the student received one point if he/she correctly filled in the missing word and zero points if they incorrectly filled in the missing word. The student's total points for the comprehension section were added together to get a total score for the comprehension section of the PELI book. There is no PELI Quick Check measure available for comprehension, so the Comprehension subtest was only given at pre- and post-test when the PELI books were administered.

Phonological Awareness. The Phonological Awareness subtest is available for the PELI books and the PELI Quick Check measures, and both of these assessments were given because Phonological Awareness was a skill that could improve based on the intervention. The administration for both forms of the PELI were very similar and assessed word parts and first

sounds. For the PELI books, the student was shown a picture, asked to name the first part of the word (e.g., What is the first part of the word pancake?) or the first sound in the word (e.g., What is the first sound in the word rice?), and then allowed to place the picture in a special pocket in the book. For the PELI Quick Check measures, the questions maintain the same format, but the words were presented verbally without pictures. Responses for the word parts were scored as correct if the student said the first part of the word or the first sound in the word. Any other responses were scored as incorrect. For first sounds, responses were scored from zero to two points. A two point response contained only the first sound in the word, a one point response was giving a word part or a combination of first sounds (e.g., /ca/ for cat), and a zero point response was repeating the word or any other incorrect response. The Phonological Awareness subtests were given at pre- and post-test with the PELI books, and twice a week when the PELI Quick Check measures were administered.

Vocabulary and Oral Language. The Vocabulary and Oral Language subtest is available for the PELI books and the PELI Quick Check measures, and both of these assessments were given because Vocabulary was a skill expected to improve based on the intervention. The administration of the Vocabulary and Oral Language subtest for both forms of the PELI were very similar and assessed children's ability to describe common objects. For the PELI books, children were shown an array of pictures and asked to name each picture. Each picture named correctly was worth one point. Then the child was asked to tell the examiner everything they knew about five of the pictures they named. These words were predetermined in the assessment, and if the child did not correctly name the item previously, the examiner told the child the name of the item before asking them to describe it. If the child did not respond to the initial prompt (e.g., "Tell me everything you can about a spoon") the examiner provided follow up prompts

(e.g., "What do you do with a spoon?"). Only one follow up prompt could be given for each word. The child's responses were scored on a scale of zero to five. A child received a score of zero if they provided no response even after being prompted. If a child provided a correct one-word response, they receive a score of one. If a child provided a phrase, two-element sentence, or a grammatically incorrect simple sentence, they received two points. A three-point response contained a grammatically correct three-element sentence or a grammatically incorrect expanded sentence. A four-point response contained a grammatically correct sentence with four or more elements, and a five point response was a grammatically correct compound sentence.

For the PELI Quick Check measures, the child was verbally given five words and asked to tell the examiner everything they knew about each word. While these forms did not include the picture naming component like the PELI books, the prompting and scoring procedures were the same as the Vocabulary and Oral Language subtests of the PELI books.

Intervention Integrity Measures

Intervention integrity was measured through parent completed reading guides and audio recordings of the intervention sessions. Specifically, parents were asked to write the date they read the story to their child and then check off each step they completed on their reading guide. The total number of steps on each reading guide was calculated, and then the percentage of steps that the parents completed was determined. The parents also indicated if they read each story more than once. To ensure that parents were accurately filling out the reading guides, one recorded reading session was listened to for each parent-child dyad. Specifically, the transcribed reading sessions from the last week of intervention, used to calculate parent and child mathematical dialogue, were also used to examine the intervention integrity for all dyads. A blank copy of the selected reading guide was filled out as the examiner listened to the audio

recording, and each step that the parent-child dyad completed was marked. Once this was done, the percent of agreement between the parent and examiner checklists was calculated. The percent agreement was calculated by dividing the number of steps that the parent and the examiner rated the same way by the total number of steps on the checklist.

Social Validity Measures

The Shared Storybook Reading Project Rating Scale was used to measure parent's thoughts about the importance and practicality of the intervention. This measure was adapted from Von Brock and Elliot's Behavior Intervention Rating Scale (BIRS; 1987), and it is the same measure that Hojnoski and colleagues (2014) used in their early numeracy intervention study. Previous studies have shown that the BIRS (Von Brock & Elliot, 1987) had high levels of reliability and validity. Specifically, the reliability of the measure yielded an alpha of 0.97. Additionally, concurrent validity was calculated by comparing the BIRS to the Semantic Differential (SD; Kazdin, 1980), and concurrent validity between the measures ranged from 0.52 to 0.78 (Elliot & Treuting, 1991).

The scale allows parents to provide feedback regarding the intervention through questions such as, "Our participation in this project was effective in supporting my child's mathematical development." Parents used a five point likert scale ranging from one (Strongly Disagree) to five (Strongly Agree) to respond to each question. The responses were added together, and an average was calculated. Higher scores indicated higher levels of satisfaction. These procedures are similar to those used in previous studies (Hojnoski, et. al., 2014).

Data Analysis

The early numeracy and literacy data collected throughout the study was analyzed in several ways. First, progress monitoring data collected across multiple time points for the early

numeracy measures (i.e., cardinality, ordinality, number naming, matching quantities to numerals, and partitioning equal quantities) and early literacy measures (i.e., phonological awareness and vocabulary) were displayed through graphs and visually analyzed. Visual analyses included calculating level, trend, variability, immediacy of the effect, and consistency of data patterns. A masked visual analysis was used to test randomization. Additionally, inferential statistical analysis were conducted through multi-level modeling. Finally, descriptive statistics were used for measures of parent-child mathematical dialogue, the early literacy pre- and post-tests (using the PELI books), intervention integrity, and social validity. The analytic strategies are explained further in the following sections.

Visual analysis

Visual analysis was completed using the guidelines recommended by the What Works Clearinghouse (WWC; Kratochwill, Hitchcock, Horner, Levin, Odom, Rindskopf, & Shadish, 2010). First, student baseline data collected for early numeracy and literacy patterns were analyzed for stability. Baseline data indicates stability and predictability if the baseline trend is neutral, in the opposite direction of the expected behavior change (i.e., negative trend), or increasing at an equal rate across participants. Because students were enrolled in a preschool setting, we expectd some growth in numeracy and literacy skills even during the baseline phases; however, we expected average student scores to increase as the intervention progressed. Next, the intervention phase data were examined to detect predictable patterns of the dependent variables. Once patterns were identified, the baseline and intervention phases were compared to determine if introducing the storybook reading intervention was associated with any changes in children's early numeracy or early literacy achievement. Finally, the data were examined for treatment effects by looking at the changes in data patterns across the four participants.

When analyzing and comparing phases in the four steps given by the WWC (Kratochwill, et al., 2010), six variables were examined including: (1) the level (i.e., mean), (2) trend (i.e., slope), (3) variability (i.e., range of data deviating from the trend), (4) immediacy of effect, (5) overlap, and (6) consistency of data patterns in each phase (Kratochwill et al., 2010). A treatment effect was considered present if there was a change in level between the baseline and intervention phases of the study. Specifically, data patterns are expected to show a positive trend and an increase in level if a treatment effect is present. Immediate effects and greater consistency in data patterns were not anticipated given that the intervention was expected to reinforce skills over time, but these factors may indicate greater strength in the intervention than if they were not present.

Overlap of data between baseline and intervention phases was also examined using the Tau-U for each participant (Parker, Vannest, Davis, & Sauber, 2011). This is a non-parametric effect size measuring the percent of non-overlapping data minus overlapping data (Parker, Vannest, & Davis, 2014). Tau-U was chosen due to it's sensitivity to baseline trend and precision-power (Parker, Vannest, Davis, & Sauber, 2011).

Masked Visual Analysis

A masked visual analysis was used to replace a traditional randomization test in the current study. This was done to control Type 1 error rates (Ferron & Jones, 2006). The test was conducted by a visual analyst, who was blind to the participants' condition assignments. The visual analyst was given one set of graphs for each early numeracy and early literacy assessment. The graphs were placed in random order, and graphs were randomized separately for each measure so that the graphs were not presented in the same random order. The masked visual analyst then estimated when Dyads 1, 2, and 3 started the intervention phase of the study (Ferron

& Jones, 2006). Due to the limited amount of data accumulated for Dyad 4, the data for this participant was not included in the masked visual analysis. However, the analyst was informed that there were originally four participants in the study, and that there were four possible intervention start points for the three dyads. The visual analyst's estimates were used to calculate a formal probability, or *p* value. The *p* value was calculated by dividing the number of attempts it takes the visual analyst to correctly identify the order that the participants entered the intervention phase by the total possible assignments of participants to baseline lengths ($n = 24$). The more attempts required for the visual analyst to correctly estimate the order that participants entered the intervention phase, the higher the probability that any intervention effects were due to chance. If the *p* value exceeded a predetermined level ($\alpha = .05$), then the primary investigator would fail to reject the null hypothesis and no treatment effects would be assumed.

Multi-level Modeling

In addition to the use of visual analyses, hierarchical linear modeling (HLM) was used to synthesize academic skill changes across the four participants. Specifically, multi-level modeling provides estimates of effects from the intervention. A Level-1 model was used to analyze dependent variable data for the four parent-child dyads, while a Level-2 model examined the impact of the intervention across all participants by calculating an average effect size. The Level-1 model used was:

$$y_{ij} = \beta_{0j} + \beta_{1j}\chi_{ij} + \beta_{2j}t_{ij} + r_{ij}$$

This equation explains participant response to intervention based on the intervention phase (e.g., baseline or intervention), time (e.g., number of weeks) and the random error. Specifically, y_{ij} is the response of person *j* at time *i*, and χ_{ij} is the phase for person *j* at time *i.* The variable χ_{ij} is considered a dummy variable that represents the phase of the study, so $\chi_{ij} = 0$ during the baseline

phase and $\chi_{ij} = 1$ during the intervention phase. β_{0j} and $(\beta_{0j} + \beta_{1j})$ represent the predicted responses for participant j during the baseline and intervention phases. β_{1j} also represents the individual participant treatment effect for participant j. In addition, β_{2j} represents the change in performance over time for participant j, and t_{ij} represents the time for the i^{th} observation of participant j. Finally, r_{ij} represents random error in the equation, or the difference between the observed and the expected values for participant *j* at time point *i*.

The Level-2 model will be calculated using these additional formulas:

$$\beta_{0j} = y_{00} + u_{0j} \; and \; \beta_{1j} = y_{10} + u_{1j} \; and \; \beta_{2j} = y_{20} + u_{2j}$$

In these equations y_{00}, y_{10}, and y_{20} are the average baseline level, treatment effect, and slope, respectively. Additionally, the equations calculate the residual where u_{0j}, u_{1j}, *and* u_{2j} show the difference between participant j's response and the average baseline or intervention level and trend, respectfully.

These HLM methods were used to examine the impact of the intervention on all dependent variables (i.e., early numeracy and early literacy). The Kenward-Roger strategy was used to calculate degrees of freedom as recommended in (Ferron, Farmer, & Owens, 2010). The model used allowed for a change in level at the beginning of intervention, and a constant trend in baseline and intervention phases. By allowing for a constant trend in the data, the time at which the treatment effect (i.e., change in level) is measured does not impact the results because the trend in baseline and intervention are parallel. This results in the treatment effect being the same despite the time at which it is measured. This model was chosen as the most representative of the data due to participants' age at the time of intervention. Because students were exiting pre-school and about to start kindergarten at the time of intervention, the concepts being taught during the shared parent-child mathematical storybook sessions were likely concepts that the

children had been introduced to during preschool. This suggested that the mathematical concepts were being reinforced from previous exposure, instead of exposing the students to new material, and were, therefore, more likely to lead to a change in level (i.e., increase in average scores) than a change in slope (i.e., increase in the rate at which children learn the topic) making the chosen model the most appropriate fit for the data.

Descriptive Statistics

Descriptive statistics were used for measures of parent-child mathematical dialogue, inter-rater reliability for parent-child mathematical dialogue coding and PELI vocabulary scoring, the pre- and post-tests using the PELI books, intervention integrity, and social validity. The following sections will describe the descriptive statistics that used for each of these measures.

Parent-Child Math Dialogue. One parent-child reading session from the baseline and intervention phases of the study was transcribed. Transcriptions only included extra-textual dialogue**,** and text from the storybooks was not transcribed or coded. Once the transcriptions were complete, parent and child utterances were categorized as containing math or non-math related speech. Total speech, math speech, and percent of math speech was calculated for both parents and children. Additionally, the sum of parent and child total speech, math speech, and percent of math speech were determined. Calculating the percent of math speech for parents and children in both separate and summative forms provided data on how the math dialogue was distributed between the parent-child dyads.

Inter-Rater Agreement. Due to the small sample of parent-child mathematical dialogue and the complexity of scoring the PELI Vocabulary/ Oral Language assessments, inter-rater reliability was calculated for both of these measures. Summaries of the the inter-rater agreement

calculations for the sample of parent-child mathematical dialogue and the PELI Vocabulary/ Oral Language are provided in the sections below.

Parent Child Math Dialogue Inter-Rater Agreement. Due to the small sample of parent-child math dialogue transcriptions that were coded, inter-rater reliability was calculated to ensure accuracy when coding math and non-math speech. Two independent raters coded the mathematical dialogue in one transcription of the parent-child book reading sessions. The percentage of inter-rater reliability was calculated by comparing the codes for the transcription and dividing the number of coding agreements by the number of coding agreements plus disagreements. There was 81% agreement in coding of mathematical dialogue between the two raters. All disagreements in coding were examined by a third rater who made all final coding decisions.

PELI Vocabulary Inter-Rater Agreement. Due to the objectivity in scoring the PELI Vocabulary assessments, inter-rater agreement was calculated to ensure accuracy when scoring this measure. Two independent raters scored the PELI Vocab measures from each assessment session throughout the study. The percentage of inter-rater agreement was calculated by comparing the scores for each assessment and dividing the number of scoring agreements by the number of scoring agreements plus disagreements. There was 77.27% agreement in scoring between the two raters. Any disagreements in scoring were examined by a third rater who made all final scoring decisions. Table 7 shows the percentage of assessment items scored the same by both raters, and the percentage of assessment items that differed in score by 1- and 2-raw points.

Table 7

Descriptive Statistics for PELI Vocabulary Inter-Rater Agreement

% Items Scored the Same	% Items Scored with 1-point Difference	% Items Scored with 2-point Difference
77.27%	19.09%	3.63%

Early Literacy Pre- and Post-Tests. One of the PELI books was administered as a pre-test and one was administered as a post-test during the baseline and intervention phases, respectively. The percent of total items correct were calculated to determine if there was an increase in children's early literacy skills from the baseline to intervention phase. Additionally raw scores on the PELI pre- and post tests were reported and compared to beginning and end of year benchmark expectations for four to five year old students as outlined by Dynamic Measurement Group (2015). In addition to examining raw scores and percent accuracy for the PELI pre- and post-test measures, the PELI Composite Score and the PELI Language Index were calculated. The PELI Composite score is a combination of the subtest raw scores obtained from the PELI Books and provides an overall measurement of children's early literacy skills (Dynamic Measurement Group, 2015). The following formula is used to calculate the PELI Composite Score as indicated by the Dynamic Measurement Group (2015):

> (2*Alphabet Knowledge)+(4*Comprehension)+(4*Phonological Awareness)+(3*Vocabulary/Oral Languare)

Similarly, the PELI Language Index provides a composite score that looks at children's overall language skills (Dynamic Measurement Group, 2015). This is done by taking children's raw scores on the Comprehension and Vocabulary/ Oral Language subtests into account. The

following formula is used to calculate the PELI Language Index as indicated by the Dynamic Measurement Group (2015):

(4*Comprehension)+(3*Vocabulary/Oral Language)

Intervention Integrity. Two measures of intervention integrity were calculated. First, parents marked each step that they completed during the shared storybook reading sessions on their reading guides. The total number of steps on each reading guide was calculated, and then the percentage of steps that the parents completed was determined. This was done for all of the reading guides. Then, to ensure that parents were accurately filling our their reading guides, one recorded reading session was listened to for each parent-child dyad. Specifically, the transcribed reading sessions from the last week of intervention, used to calculate parent and child mathematical dialogue, were also used to examine the intervention integrity for all dyads. The primary investigator took a blank copy of the selected reading guide, and marked each step completed by the parent child dyad as they listened to the recording. Once this was done, the percent agreement was calculated by dividing the number of steps that the parent and observer rated the same way by the total number of steps on the checklist.

Social Validity. Parents used a five-point likert scale, ranging from one (strongly disagree) to five (strongly agree), to rate the practicality and importance of the intervention. The responses were added together, and an average was calculated for each parent. Higher scores indicated higher levels of satisfaction.

CHAPTER FOUR: RESULTS

This chapter includes the results of the visual, descriptive, and statistical analyses performed. The chapter will begin with a discussion of intervention integrity, followed by a comparison of the parent-child mathematical dialogue pre- and post- intervention. Next, the results of the graphed visual analyses, masked visual analysis and the HLM results will be presented. Then, data gathered from the pre- and post-intervention PELI assessments, and treatment satisfaction measures will be discussed. Finally, a brief overview of the results will be provided at the end of the chapter.

Intervention Integrity

Integrity of the intervention was evaluated by examining the parent's reading guide checklists each week of the study. Parents were asked to check off each step of the reading guide as they completed the reading activities with their child. The total number of steps on each reading guide was used to calculate the percentage of steps that the parents completed on the reading guides each week. This was done by taking the sum of the steps on the three weekly reading guides, and dividing the total steps possible per week by the total steps completed per week. The average percentage of steps completed for Dyad 1 was 100% with a standard deviation of 0. For dyad 2, the mean percentage of steps completed on the weekly reading guides was 90% with a standard deviation of 19%. The dyad only completed checklists for two of the three reading guides during week four of the intervention, which caused the intervention integrity to decrease overall. For Dyad 3, the mean percentage of steps completed on the weekly reading guides was 99% with a standard deviation of 2%. Dyad 4 completed two weeks of

intervention prior to dropping out of the study, however this family only returned one set of reading guides. Dyad 4 completed 33% of the steps on the reading guides returned. The dyad only completed reading guides for two of the three books provided during week three of the study. Additionally, Dyad 4 did not complete all of the steps on the reading guides that were utilized during reading sessions. This likely caused the intervention integrity to be low overall. Table 8 shows the percentage of steps completed on the weekly reading guides for each dyad throughout the intervention phase.

Table 8

Intervention Integrity: Percentage of Reading Guides Completed

Week	Dyad 1	Dyad 2	Dyad 3	Dyad 4
3	100%	------	------	33%
4	100%	61%	------	No reading guides returned
5	100%	100%	97%	------
6	No reading guides returned	100%	100%	------
7	100%	98%	100%	------

An additional measure of intervention integrity was completed to ensure that parents were accurately filling out their reading guides. One recorded reading session was listened to for each parent-child dyad. Specifically, the transcribed reading sessions from the last week of intervention were also used to examine the intervention integrity for Dyads 1 and 2. Dyad 3 had difficulty with the audio recorder during the last week of intervention, and none of the book reading sessions were recorded. Therefore, the last book read during the next to last week of the study (i.e., week six) was transcribed and analyzed for intervention integrity for Dyad 3. As the primary investigator listened to the recorded reading sessions, each reading guide step completed was checked off. The percent agreement was then calculated by dividing the number of steps that the parent and observer rated the same way (i.e., completed or not completed) by the total

number of steps on the checklist. The percent agreement for Dyad 1 was 0%. The parent in Dyad 1 indicated that 100% of the steps on the reading guide had been completed. However, upon listening to the recording, the primary investigator discovered that none of the questions on the reading guide had been completed. The parent did incorporate extra-textual dialogue into the reading session, but it did not follow the reading guide. To ensure that the sample recording chosen was not a misrepresentation of the recordings collected, two additional book reading sessions from the last week of intervention were examined by listening to the recordings. These recordings also had 0% agreement between the parent in Dyad 1 and the primary investigator, and showed a similar pattern of the parent incorporating dialogue into the reading session but not following the reading guide. This suggests that the results obtained for Dyad 1 should be interpreted with caution because the intervention fidelity was questionable. One audio recording was examined for both Dyads 2 and 3, and there was 100% agreement between the parent and primary investigator regarding the reading guide steps completed. No audio recordings were returned from Dyad 4 so no additional intervention integrity data was available.

Parent-Child Mathematical Dialogue Pre- and Post Intervention

The percentage of parent and child mathematical dialogue and the number of parent, child, and total math utterances are presented in Table 9 and Table 10 respectively. Mathematical dialogue was not calculated for Dyad 4 because no recordings of the shared storybook reading sessions were returned to the primary investigator. Dyads 1 and 2 both showed an increase in both the percentage of mathematical dialogue and the number of math utterances from baseline to intervention. Dyad 3 showed an increase in the number of math utterances from baseline to intervention, but the percent of math dialogue remained the same for the parent and decreased for the child. It should be noted that the book Dyad 3 was reading

during the transcribed baseline session had suggested mathematical activities at the end of the storybook. While the parent and child did not engage in the exact mathematical activities provided in the back of the book, the parent did use the pictures from the suggested activities pages to ask her child math related questions. The presence of these suggested mathematical activities may have resulted in an inflated sample of mathematical dialogue during the baseline phase for Dyad 3. Two additional shared book-reading sessions were listened to for Dyad 3 during the second week of the baseline phase (one story with math activities at the end of the book and one without), and no dialogue was present outside the context of the storybook. This further suggests that the reading session coded for Dyad 3 may be an over representation of the amount of math dialogue during the baseline phase.

Table 9

Percentage of Parent-Child Mathematical Dialogue

	Baseline		Intervention	
	% Parent Math Talk	% Child Math Talk	% Parent Math Talk	% Child Math Talk
Dyad 1	0.00%	0.00%	43.05%	59.37%
Dyad 2	0.00%	0.00%	47.51%	70.59%
Dyad 3	50.00%	84.21%	51.90%	46.60%

Table 10

Number of Parent-Child Mathematical & Total Utterances

	Baseline Phase		Intervention Phase	
	Parent Math Utterances (Total Parent Utterances)	Child Math Utterances (Total Child Utterances)	Parent Math Utterances (Total Parent Utterances)	Child Math Utterances (Total Child Utterances)
Dyad 1	0 (0)	0 (0)	31 (72)	19 (32)
Dyad 2	0 (10)	0 (7)	86 (181)	36 (51)
Dyad 3	11 (22)	16 (19)	109 (210)	48 (103)

Visual Analysis

A four step process was used to identify treatment effects. Specifically, a treatment effect was determined to be present if the data patterns of the dependent variables were stable during baseline, and a positive change in trend and level was present between the baseline and intervention phases of the study. Immediate effects and greater consistency in data patterns were not anticipated given the design of the intervention (i.e., to increase skills over time), but these factors could also indicate greater strength in the intervention than if they were not present. Finally, at least three demonstrations of an effect were required, across dyads, to support that the shared storybook reading intervention was the reason for a change in early numeracy and early literacy skills.

In the following sections, treatment effects are explored by examining level (i.e., mean), trend (i.e., slope), variability (i.e., range and standard deviation), immediacy of effect, overlap, and consistency of data patterns across comparable phases. The results for all early numeracy and early literacy measures are discussed, and graphed data is included.

eNumeracy: Early Math Assessments

Counting Arrays. A graphical representation of students' scores on the Counting Arrays subtest is presented in Figure 1 at the end of this chapter. All four dyads had a trend during the baseline phase. Dyads 1 and 4 both showed a positive trend in baseline, while Dyads 2 and 3 showed a negative trend in baseline data with Dyad 3 having the greatest negative slope. Additionally, all dyads had variability in their baseline scores, with Dyad 2 showing the most consistent scores across the baseline phase. Dyads 1, 3, and 4 showed the most variability in scores with student performance ranging from 63 to 100 percent. Dyads 2 and 3 showed a slight change in trend during the intervention phase with the students' scores increasing over time.

Dyad 1 showed a negative trend in the intervention phase, and Dyad 4 showed no trend in the intervention phase. The mean level of assessment scores decreased for Dyads 1 and 3 (see Table 11) in the opposite direction of expected treatment effects. Dyads 2 and 4 showed a slight increase in mean level of assessment scores from baseline to intervention. There was great variability in scores during the intervention phase for Dyads 1 and 3 with scores ranging from 38 to 100 percent, and 63 to 100 percent, respectively. Dyad 2 and 4 showed less variability in the intervention phase than in the baseline phase.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 12). Based on these analyses, all four dyads showed weak non-parametric effect sizes. Dyads 1 and 3 showed negative effect sizes, which indicate that the data moved in the opposite direction expected based on treatment. All four dyads had a high degree of overlapping data across phases, which is likely due to the variability in scores and ceiling effects. Across all four dyads, there was no immediate effect from the intervention.

Table 11

Descriptive Statistics for eNumeracy, Counting Arrays Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	81.67% (13.69%)	66.67%-100.00%	70.00% (16.76%)	37.50%-100.00%
Dyad 2	93.45% (4.72%)	87.50%-100.00%	94.79% (4.31%)	91.67%-100.00%
Dyad 3	87.50% (12.79%)	62.5%-100.00%	79.86% (17.16%)	62.50%-100.00%
Dyad 4	88.54% (17.80%)	62.5%-100.00%	100.00% (0.00%)	100.00%

Table 12

Non-Overlap Statistics for eNumeracy, Counting Arrays Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	-0.4	0.18	-0.23	0.5
Tau-U Trend Corrected	-0.38	0.25	0.23	0.125

Ordinal Position. A graphical representation of students' scores on the Ordinal Postion subtest is presented in Figure 2 at the end of this chapter. Dyads 1 and 2 had a positive trend during the baseline phase and a large amount of variability. Dyad 2 had the greatest variability in scores during baseline with scores ranging from 0% to 60% accuracy. It should be noted that one data point was omitted for Dyad 2 during the baseline phase of the study because the parent was helping the child during the assessment (i.e., telling the child how to figure out the assessment questions). It was believed that this lead to a falsely inflated score during this one assessment period, and, therefore, this data point was not included in any analyses. Dyad 1 also showed some variability with scores ranging from 0% to 30% accuracy. In contrast, Dyads 3 and 4 showed no trend or variability in scores during the baseline sessions, and consistently scored 0% accuracy across all baseline sessions.

During the intervention phase, there was a negative change in trend for both Dyads 1 and 2. There was no change in trend for Dyads 3 and 4. There was an increase in the mean level of assessment scores for Dyads 2 and 3, while Dyad 1 showed a decrease in the mean level of scores. Dyad 4 showed no change in mean level of scores from baseline to intervention. The mean level scores for each dyad are presented in Table 13. The variability in scores decreased for Dyad 1 during the intervention phase, with scores ranging from 0% to 20% accuracy. Dyad 2 continued to show variability in the intervention phase of the study, with scores ranging from 40% to 100% accuracy. Dyad 3 showed an increase in variability, with scores ranging from 0% to 30% accuracy. However, this student only received one score of 0%, and his remaining 5 scores ranged from 20% to 30% accuracy. Dyad 4 continued to show no variability in scores during the intervention phase.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 14). Based on these analyses, three dyads showed moderate to strong non-parametric effect sizes, and one dyad showed a weak non-parametric effect size. However, Dyad 1 showed negative effect sizes, which indicate that the data moved in the opposite direction expected based on treatment. Dyads 2 and 3 showed the most noticeable increase in accuracy from baseline to intervention. Similarly, Dyad 2 and 3 showed immediate effects from the intervention. There was an immediate effect of the intervention for Dyad 1 also, however, the effect was not in the direction expected based on the treatment. Observations from the assessment sessions with the student in Dyad 1 suggest that the child was consistently guessing on the Ordinal Position tasks. For instance the student consistently started counting on the right side of the page and always started the counting sequence with "third" during these tasks. . Dyad 4 showed no immediate effect from the intervention.

Table 13

Descriptive Statistics for eNumeracy, Ordinal Position Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	18.00% (10.95%)	0.00%-30.00%	2.00% (6.32%)	0.00%-20.00%
Dyad 2	48.33% (24.01%)	0.00%-60.00%	85.00% (20.00%)	40.00%-100.00%
Dyad 3	0.00% (0.00%)	0.00-0.00%	23.33% (12.11%)	0.00%-30.00%
Dyad 4	0.00% (0.00%)	0.00%-0.00%	0.00% (0.00%)	0.00% - 0.00%

Table 14

Non-Overlap Statistics for eNumeracy, Ordinal Position Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	-0.72	0.79	0.83	0.00
Tau-U Trend Corrected	-0.82	0.68	0.83	0.00

Matching Quantities to Numerals. A graphical representation of students' scores on the Matching Quantitites to Numerals subtest is presented in Figure 3 at the end of this chapter. Dyads 2, 3, and 4 had a positive trend during the baseline phase, while Dyad 1 had a negative trend in baseline. All dyads demonstrated a large amount of variability during baseline. Dyad 1 had the greatest variability in scores during baseline with scores ranging from 0% to 75% accuracy. Dyads 2 and 3 also showed some variability with scores ranging from 0% to 62.5% accuracy and from 37.5% to 100% accuracy, respectively. Dyad 4 had scores ranging from 62.5% to 100%.

During the intervention phase, there was a negative trend for Dyads 1, 3 and 4. Dyad 2 continued to show a positive trend in data, however, the rate of improvement over time decreased from baseline to intervention. There was an increase in the mean level of assessment scores for Dyads 1 and 2, while Dyads 3 and 4 showed a slight decrease in the mean level of scores. The mean level scores for each dyad are presented in Table 15. While the variability in scores decreased across all three dyads, all dyads continued to show variability in scores in the intervention phase of the study. The scores for Dyad 1 ranged from 0% to 62.5% accuracy during the interventions phase. Dyad 2 showed the least variability in scores across participants during the intervention phase, with scores ranging from 87.5% to 100% during the intervention phase. Dyad 3 showed a decrease in variability, with scores ranging from 50% to 87.5% accuracy. However, this student's highest score during the intervention phase of the study was lower than his highest score during the baseline phase of the study. Dyad four had scores ranging from 50% to 75% accuracy.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 16). Based on these analyses, Dyads 1 and 3 showed weak non-

parametric effect sizes due to the large amount of variability and overlap in data. Dyad 3 showed negative effect sizes, which indicate that the data moved in the opposite direction expected based on treatment. In contrast, Dyads 2 and 4 showed strong non-parametric effect sizes even when correcting for trend in the baseline data. However, Dyad 4 also showed negative effect sizes, indicating the the data moved in the opposite direction of anticipated treatment effects. Dyad 2 was the only dyad to show an immediate effect from the intervention.

Table 15

Descriptive Statistics for eNumeracy, Matching Quantities to Numerals Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	22.50% (33.54%)	0.00%-75.00%	28.75% (21.28%)	0.00%-62.50%
Dyad 2	26.79% (28.35%)	0.00%-62.50%	96.88% (5.78%)	87.50%-100.00%
Dyad 3	76.56% (18.22%)	37.50-100.00%	75.00% (15.81%)	50.00%-87.50%
Dyad 4	81.25% (21.65%)	62.50%-100.00%	62.50% (17.67%)	50.00%-75.00%

Table 16

Non-Overlap Statistics for eNumeracy, Matching Quantities to Numerals Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	0.18	1.0	-0.041	-0.5
Tau-U Trend Corrected	0.16	0.87	-0.14	-0.5

Partitioning Equal Quantities. A graphical representation of students' scores on the Partitioning Equal Quantities subtest is presented in Figure 4 at the end of this chapter. Dyads 1 and 2 both had a positive trend during the baseline phase and a large amount of variability. The first dyad had scores ranging from 0% to 37.5% accuracy during the baseline phase. Dyad 2 had the greatest variability in scores during baseline with scores ranging from 37.5% to 87.5% accuracy. Dyad 3 showed no trend in baseline scores, and showed less variability than the other two dyads with scores ranging from 87.5% to 100% accuracy. Dyad 4 was the only dyad with a negative trend during baseline, and had scores ranging from 37.5% to 62.5%.

During the intervention phase, there was an increase in trend for all dyads. There was an increase in the mean level of assessment scores for Dyads 1 and 2, while Dyads 3 and 4 showed a slight decrease in the mean level of scores. The mean level scores for each dyad are presented in Table 17. Variability in scores increased for Dyads 1 and 3, and decreased for Dyads 2 and 4. However, all dyads continued to show variability in the intervention phase of the study. The scores for Dyad 1 ranged from 0% to 50% accuracy during the interventions phase. Both Dyads 2 and 3 had scores ranging from 62.5% to 100% during the intervention phase. Dyad 4 had scores ranging from 37.5% to 50% during intervention.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 18). Based on these analyses, Dyads 1 and 2 showed weak to moderate non-parametric effect sizes. Dyad 3 showed negative effect sizes, which indicate that the data moved in the opposite direction expected based on treatment. Dyad 4 also showed a negative effect size, and no effect when controlling for trend in baseline data. None of the dyads showed an immediate effect from the intervention.

Table 17

Descriptive Statistics for eNumeracy, Partitioning Equal Quantities Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	15.00% (16.30%)	0.00%-37.50%	27.50% (17.48%)	0.00%-50.00%
Dyad 2	67.86% (17.46%)	37.50%-87.50%	79.69% (11.45%)	62.50%-100.00%
Dyad 3	93.75% (6.68%)	87.50%-100.00%	85.42% (14.61%)	62.50%-100.00%
Dyad 4	50.00% (10.21%)	37.50%- 62.50%	43.75% (8.84%)	37.50%-50.00%

Table 18

Non-Overlap Statistics for eNumeracy, Partitioning Equal Quantities Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	0.4	0.36	-0.33	-0.375
Tau-U Trend Corrected	0.38	0.27	-0.33	0.0

Number Recognition. A graphical representation of students' scores on the Number Recognition subtest is presented in Figure 5 at the end of this chapter. All dyads had a positive trend and variability in scores during the baseline phase. The first dyad had scores ranging from 0% to 15% accuracy during the baseline phase, and had the least variability in baseline across participants. Dyads 2 and 3 both had scores ranging from 45% to 100% accuracy during the baseline phase. However, the variability in scores for Dyad 2 was a result of a steady increase in scores across the baseline phase, whereas Dyad 3 consistently scored between 90% and 100% accuracy with the exception of one assessment session on August 11. It should be noted that during this assessment session, the student in Dyad 3 counted from one to ten on the second half of the assessment instead of naming the numbers presented, even though the student had answered previously administered assessment questions correctly. This could have resulted in an inaccurately low score on this date. Dyad 4 had scores ranging from 50% to 80% during baseline.

During the intervention phase, there was an increase in trend for Dyads 1 and 4, and a decrease in trend for Dyads 2 and 3. There was an increase in the mean level of assessment scores for all three dyads. The mean level scores for each dyad are presented in Table 19. Variability in scores increased for Dyads 1 and 4, and decreased for Dyad 2. Dyad 3 showed no variability in scores during the intervention phase with the student consistently scoring 100% on the assessments. The scores for Dyad 1 ranged from 0% to 90% accuracy during the interventions phase. Dyad 2 had scores ranging from 95% to 100% accuracy. Dyad 4 had scores ranging from 65% to 85% during intervention.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 20). Based on these analyses, Dyads 1, 3, and 4 showed weak to

moderate non-parametric effect sizes. Dyad 2 showed moderate to strong non-parametric effect sizes. Dyad 1 was the only group that showed an immediate effect from the intervention.

Table 19

Descriptive Statistics for eNumeracy, Number Recognition Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	6.00% (5.47%)	0.00%-15.00%	41.50% (39.30%)	0.00%-90.00%
Dyad 2	72.86% (22.70%)	45.00%-100.00%	99.38% (1.77%)	95.00%-100.00%
Dyad 3	91.88% (19.26%)	45.00-100.00%	100.00% (0%)	100.00%-100.00%
Dyad 4	67.50% (13.23%)	50.00%-80.00%	75.00% (14.14%)	65.00%-85.00%

Table 20

Non-Overlap Statistics for eNumeracy, Number Recognition Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	0.44	0.84	0.25	0.375
Tau-U Trend Corrected	0.38	0.53	0.062	0.125

Total Math Score. A graphical representation of students' scores on the eNumeracy Total Math Score is presented in Figure 6 at the end of this chapter. Dyads 1, 2, and 4 all had a positive trend in slope during the baseline phase, while Dyad 3 had a negative slope. The first dyad had scores ranging from 30% to 40% accuracy during the baseline phase, and had the least variability in baseline across participants. Dyads 2 and 3 both had scores ranging from 48.57% to 85.71% accuracy and 64.29% to 81.43% accuracy, respectively. Dyad 4 had scores ranging from 54.29% to 74.29%.

During the intervention phase, there was an increase in trend for Dyads 1, 3, and 4, and a decrease in trend for Dyad 2. There was an increase in the mean level of assessment scores for all dyads. The mean level scores for each dyad are presented in Table 21. Variability in scores increased for Dyads 1 and 3, and decreased for Dyads 2 and 4. The scores for Dyad 1 ranged from 32.86% to 60% accuracy during the intervention phase. Dyad 2 had scores ranging from

84.29% to 100% accuracy, and Dyad 3 had scores ranging from 68.57% to 88.57% accuracy. Dyad 4 had scores ranging from 65.71% to 70%.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 22). Based on these analyses, Dyads 1, 3, and 4 showed weak to moderate non-parametric effect sizes. Dyad 2 showed moderate to strong non-parametric effect sizes. None of the participants showed an immediate effect from the intervention.

Table 21

Descriptive Statistics for eNumeracy, Total Math Score

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	36.57% (3.99%)	30.00%-40.00%	42.57% (12.02%)	32.86%-60.00%
Dyad 2	70.99% (11.75%)	48.57%-85.71%	93.21% (4.81%)	84.29%-100.00%
Dyad 3	75.71% (6.61%)	64.29%-81.43%	77.62% (8.55%)	68.57%-88.57%
Dyad 4	64.64% (8.36%)	54.29%-74.29%	67.86% (3.03%)	65.71%-70.00%

Table 22

Non-Overlap Statistics for eNumeracy, Total Math Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	0.2	0.96	0.083	0.25
Tau-U Trend Corrected	0.14	0.66	0.18	0.00

PELI

Phonological Awareness. A graphical representation of students' scores on the PELI, Phonological Awareness subtest is presented in Figure 7 at the end of this chapter. Dyad 1 showed a negative trend during the baseline phase, while Dyads 2, 3, and 4 all had a positive slope. All dyads showed variability in scores during the baseline phase of the study. The first dyad had scores ranging from 20% to 53.33% accuracy during the baseline phase. Dyads 2 and 3 both had scores ranging from 46.67% to 100.00% accuracy and 0% to 46.67% accuracy, respectively. Dyad 4 had scores ranging from 33.33% to 46.67%.

During the intervention phase, there was an increase in trend for Dyad 1, and a decrease in the positive trend for Dyad 2. Dyads 3 and 4 showed a negative trend during the intervention phase of the study. There was an increase in the mean level of assessment scores for all three dyads. The mean level scores for each dyad are presented in Table 23. Variability in scores decreased for Dyads 1, 2, and 4, and remained the same for Dyad 3. The scores for Dyad 1 ranged from 26.67% to 46.67% accuracy during the intervention phase. Dyad 2 had scores ranging from 73.33% to 100% accuracy, and Dyads 3 and 4 both had scores ranging from 33.33% to 73.33% accuracy.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 24). Based on these analyses, Dyads 1 and 3 showed moderate non-parametric effect sizes. Dyads 2 and 4 showed weak non-parametric effect sizes. None of the participants showed an immediate effect from the intervention.

Table 23

Descriptive Statistics for PELI, Phonological Awareness Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	26.67 (15.63%)	20.00%-53.33%	35.33% (7.73%)	26.67%-46.67%
Dyad 2	81.90% (19.52%)	46.67%-100.00%	89.17% (9.38%)	73.33%-100.00%
Dyad 3	22.50% (12.81%)	0.00%-46.67%	50.00% (15.05%)	33.33%-73.33%
Dyad 4	40.00% (5.44%)	33.33%-46.67	53.33 (28.28%)	33.33%-73.33%

Table 24

Non-Overlap Statistics for PELI, Phonological Awareness Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	0.54	0.16	0.87	0.125
Tau-U Trend Corrected	0.60	-0.017	0.56	-0.25

PELI Vocabulary/ Oral Language. A graphical representation of students' scores on the PELI, Vocabulary/ Oral Language subtest is presented in Figure 8 at the end of this chapter.

Dyads 3 and 4 showed a negative trend during the baseline phase, while Dyads 1 and 2 both had a positive slope. All three dyads showed variability in scores during the baseline phase of the study. The first dyad had scores ranging from 52.00% to 76.00% accuracy during the baseline phase. Dyads 2 and 3 both had scores ranging from 56.00% to 100.00% accuracy and 64.00% to 88.00% accuracy, respectively. Dyad 4 had scores between 40.00% and 48.00%.

During the intervention phase, there was a decrease in trend for both Dyads 1 and 2. Dyads 3 and 4 showed a positive trend during the intervention phase of the study. There was an increase in the mean level of assessment scores for Dyad 1. Dyad 2 showed no change in mean level of assessment scores, and Dyads 3 and 4 showed a decrease in assessment scores. The mean level scores for each dyad are presented in Table 25. Variability in scores decreased for Dyads 1, 2, and 4, and increased for Dyad 3. The scores for Dyad 1 ranged from 56.00% to 72.00% accuracy during the intervention phase. Dyad 2 had scores ranging from 68.00% to 100.00% accuracy, and Dyad 3 had scores ranging from 52.00% to 84.00% accuracy. Dyad 4 had scores between 40.00% and 44.00%.

Analyses of overlapping data points between the baseline and intervention phases were also examined (see Table 26). Based on these analyses, all four dyads showed weak non-parametric effect sizes. None of the participants showed an immediate effect from the intervention.

Table 25

Descriptive Statistics for PELI, Vocabulary/ Oral Language Subtest

	Baseline Phase		Intervention Phase	
	Mean (SD)	Range	Mean (SD)	Range
Dyad 1	61.60% (8.76%)	52.00%-76.00%	62.80% (5.35%)	56.00%-72.00%
Dyad 2	87.00% (15.56%)	56.00%-100.00%	87.00% (10.93%)	68.00%-100.00%
Dyad 3	76.50% (8.67%%)	64.00%-88.00%	71.33% (12.50%)	52.00%-84.00%
Dyad 4	44.00% (3.26%)	40.00%-48.00%	42.00% (2.83%)	40.00%-44.00%

Table 26

Non-Overlap Statistics for PELI, Vocabulary/ Oral Language Subtest

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Tau-U	0.18	-0.102	-0.237	-0.375
Tau-U Trend Corrected	0.16	-0.143	-0.104	0.00

Masked Visual Analysis

In order to control Type 1 error rates, a masked visual analysis replaced a traditional randomization test (Ferron & Jones, 2006). A graduate student, who had completed graduate level studies in single case design research and studied masked visual analyses, was selected as the visual analyst for the current study. The analyst was given de-identified copies of the graphed participant data for each assessment measure (i.e., Counting Arrays, Ordinal Position, Matching Numerals to Quantities, Partitioning Equal Quantities, Number Recognition, eNumeracy Total Score, Phonoligical Awareness, and Vocabulary), and asked to determine when each participant entered the intervention phase of the study based on the visual data. In order for the visual analyst's estimations to show a treatment effect at the predetermined level (p = .05), the analyst needed to correctly identify participants intervention entry point on the first opportunity to examine the graphs. The visual analyst's estimates aligned correctly for the eNumeracy Ordinal Position subtest (p = 0.0417). This suggests that there was an observable treatment effect on children's performance on the eNumeracy Ordinal Position task. The visual analyst's estimations did not align correctly for any of the other early numeracy or early literacy dependent variables. This indicates that there was not an observable immediate treatment effect for children's early numeracy or early literacy skills.

Multi-Level Modeling

Hierarchical linear modeling (HLM) was used to estimate both average effect sizes and individual effect sizes across the three parent-child dyads. The model used was based on the following assumptions: (a) a constant trend in the baseline and intervention phases, (b) a change in level between baseline and intervention phases, and (c) first-order autocorrelation. Treatment effects were observed at the beginning of treatment for all student measures. In the following section, the results of children's early numeracy and early literacy skills are discussed and followed by tables of fixed effects and Empirical Bayes (EB) estimates.

eNumeracy Early Math Assessments

Counting Arrays. The average treatment effect at the beginning of the intervention phase (b = -1.00, p = 0.91) was not statistically significant. This suggests that, while the average student performance level decreased from the baseline phase to the intervention phase, there is not evidence to suggest that this change occurred due to the intervention. There was also a negative slope throughout the baseline and the intervention phases (-0.53) but this was also not statistically significant. Some variance was found in the treatment effect (82.07) but it was not statistically significant. There was no variance in slope. Autocorrelation was not statistically significant (0.044). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 28. None of the dyads had effects that differed significantly from the average treatment effect.

Table 27

Fixed Effects for eNumeracy Counting Arrays Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	87.05***	4.48	75.56	98.54
Average treatment effect	-1.00	8.46	-23.35	21.34

Table 27 (Continued)

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average slope	-0.53	1.31	-3.25	2.19

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 15.75 for baseline level, 82.07 for change in level, 0 for slope, 0.044 for autocorrelation, and 170.32*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 28

Empirical Bayes (EB) eNumeracy Counting Arrays Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	83.97	-9.58	-0.53
Dyad 2	89.72	4.45	-0.53
Dyad 3	86.39	-4.06	-0.53
Dyad 4	88.12	5.18	-0.53

Ordinal Position. The average treatment effect at the beginning of the intervention phase (b = -3.87, p = 0.71) was not statistically significant. This suggests that, while the average student performance level decreased from the baseline phase to the intervention phase, there is no support to suggest that this change occurred due to the intervention. There was a slope throughout the baseline and the intervention phases (3.89) but this was also not statistically significant. Some variance was found in the treatment effect (278.71) and the slope (25.28) but neither were statistically significant. Autocorrelation was statistically significant (-0.38). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 30. None of the dyads had effects that differed significantly from the average treatment effect.

Table 29

Fixed Effects for eNumeracy Ordinal Position Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	24.31	16.01	-26.54	75.15
Average treatment effect	-3.87	9.72	-32.95	25.19
Average slope	3.89	2.88	-5.11	12.90

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 989.12 for baseline level, 278.71 for change in level, 25.28 for slope, -0.38** for autocorrelation, and 123.91*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 30

Empirical Bayes (EB) eNumeracy Ordinal Position Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	19.33	-21.46	1.01
Dyad 2	69.67	-3.61	10.69
Dyad 3	4.41	14.63	1.64
Dyad 4	3.81	-5.05	2.24

Matching Quantities to Numerals. The average treatment effect at the beginning of the intervention phase ($b = 13.15$, $p = 0.47$) was not statistically significant. This suggests that, while the average student performance level increased from the baseline phase to the intervention phase, there is no evidence to suggest that this change occurred due to the intervention. There was a slope throughout the baseline and the intervention phases (0.77) but this was also not statistically significant. Some variance was found in the treatment effect (280.27) and the slope (40.27) but neither were statistically significant. Autocorrelation was not statistically significant (0.04). Empirical Bayes (EB) estimates for individual participants'

deviation from the average treatment effect are presented in Table 32. None of the dyads had effects that differed significantly from the average treatment effect.

Table 31

Fixed Effects for eNumeracy Matching Quantities to Numerals Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	52.95**	14.22	13.63	97.10
Average treatment effect	13.15	15.37	-46.15	61.38
Average slope	0.77	2.35	-12.08	14.14

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 554.80 for baseline level, 280.27 for change in level, 40.27 for slope, 0.04 for autocorrelation, and 459.04*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 32

Empirical Bayes (EB) eNumeracy Matching Quantities to Numerals Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	23.58	11.16	-1.11
Dyad 2	49.19	29.25	8.63
Dyad 3	70.43	8.61	-1.50
Dyad 4	68.62	3.60	-2.91

Partitioning Equal Quantities. The average treatment effect at the beginning of the intervention phase ($b = -9.03$, $p = 0.24$) was not statistically significant. This suggests that, while the average student performance level decreased from the baseline phase to the intervention phase, there is no indication that this change occurred due to the intervention. There was a slope throughout the baseline and the intervention phases (2.72) but this was also not statistically significant. Some variance was found in the treatment effect (64.77) but was not statistically

significant. There was no variance in the slope. Autocorrelation was not statistically significant (-0.25). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 34. None of the dyads had effects that differed significantly from the average treatment effect.

Table 33

Fixed Effects for eNumeracy Partitioning Equal Quantities Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	62.51**	16.10	12.50	112.51
Average treatment effect	-9.03	7.22	-25.47	7.42
Average slope	2.72	1.07	-0.50	4.94

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 994.08 for baseline level, 64.77 for change in level, 0 for slope, -0.25 for autocorrelation, and 178.68*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 34

Empirical Bayes (EB) eNumeracy Partitioning Equal Quantities Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	23.95	-9.02	2.72
Dyad 2	74.62	-0.84	2.72
Dyad 3	97.53	-15.20	2.72
Dyad 4	53.93	-11.05	2.72

Number Recognition. The average treatment effect at the beginning of the intervention phase ($b = -9.96$, $p = 0.28$) was not statistically significant. This suggests that, while the average student performance level decreased from the baseline phase to the intervention phase, there is no evidence to suggest that this change occurred due to the intervention. There was a statistically

significant slope throughout the baseline and the intervention phases (6.87). Based on the 95% confidence interval, the true slope for participants' scores likely falls between 3.19 and 10.55. No variance was found in the treatment effect or the slope. Autocorrelation was statistically significant (0.58). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 36. None of the dyads had effects that differed significantly from the average treatment effect.

Table 35

Fixed Effects for eNumeracy Number Recognition Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	74.15**	18.34	18.66	129.64
Average treatment effect	-9.96	9.18	-28.48	8.56
Average slope	6.87***	1.72	3.19	10.55

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 1200.25 for baseline level, 0 for change in level, 0 for slope, 0.58 *** for autocorrelation, and 326.87** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 36

Empirical Bayes (EB) eNumeracy Number Recognition Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	25.52	-9.96	6.87
Dyad 2	89.49	-9.96	6.87
Dyad 3	100.52	-9.96	6.87
Dyad 4	81.07	-9.96	6.87

Total Math Score. The average treatment effect at the beginning of the intervention phase (b = -6.30, p = 0.39) was not statistically significant. This suggests that, while the average student performance level decreased from the baseline phase to the intervention phase, there is

no evidence to suggest that this change occurred due to the intervention. There was a slope throughout the baseline and the intervention phases (3.39) but this was also not statistically significant. Some variance was found in the treatment effect (115.67) and the slope (2.16) but neither were statistically significant. Autocorrelation was not statistically significant (-0.09). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 38. None of the dyads had effects that differed significantly from the average treatment effect.

Table 37

Fixed Effects for eNumeracy Total Math Score

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	69.03***	8.64	41.74	96.32
Average treatment effect	-6.30	6.43	-25.60	13.01
Average slope	3.39	1.13	-0.77	7.55

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 281.74 for baseline level, 115.67 for change in level, 2.16 for slope, -0.09 for autocorrelation, and 43.09*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 38

Empirical Bayes (EB) eNumeracy Total Math Score

	Baseline Level	Treatment Effect	Slope
Dyad 1	45.51	-18.84	3.44
Dyad 2	80.57	4.46	4.57
Dyad 3	79.85	-6.12	1.97
Dyad 4	70.44	-4.70	3.20

PELI

Phonological Awareness. The average treatment effect at the beginning of the intervention phase ($b = 8.40$, $p = 0.31$) was not statistically significant. This suggests that, while the average student performance level increased from the baseline phase to the intervention phase, the data do not suggest that this change occurred due to the intervention. There was a slope throughout the baseline and the intervention phases (1.42) but this was also not statistically significant. No variance was found in the treatment effect. While there was some variance in slope (2.53), the variance was not statistically significant. Autocorrelation was not statistically significant (0.15). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 40. None of the dyads had effects that differed significantly from the average treatment effect.

Table 39

Fixed Effects for PELI Phonological Awareness Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	45.37*	13.11	7.05	83.70
Average treatment effect	8.40	8.03	-8.16	24.97
Average slope	1.42	1.86	-3.35	6.18

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 598.95 for baseline level, 0 for change in level, 2.53 for slope, 0.15 for autocorrelation, and 185.89*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 40

Empirical Bayes (EB) PELI Phonological Awareness Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	27.25	8.40	0.15
Dyad 2	80.10	8.40	1.69

Table 40 (Continued)

	Baseline Level	Treatment Effect	Slope
Dyad 3	31.81	8.40	2.53
Dyad 4	42.34	8.40	1.29

Vocabulary. The average treatment effect at the beginning of the intervention phase (b = -8.25, p = 0.20) was not statistically significant. This suggests that, while the average student performance level decreased from the baseline phase to the intervention phase, the data do not support that this change occurred due to the intervention. There was a slope throughout the baseline and the intervention phases (1.39) but this was also not statistically significant. No variance was found in the treatment effect. While there was some variance in slope (0.085), the variance was not statistically significant. Autocorrelation was not statistically significant (-0.12). Empirical Bayes (EB) estimates for individual participants' deviation from the average treatment effect are presented in Table 42. None of the dyads had effects that differed significantly from the average treatment effect.

Table 41

Fixed Effects for PELI Vocabulary Subtest

			95% CI	
Fixed Effects	Coefficient	*SE*	*LL*	*UL*
Average baseline level	70.73***	10.14	39.66	101.81
Average treatment effect	-8.25	6.12	-21.64	5.14
Average slope	1.39	1.47	-17.33	20.12

Note. CI = confidence interval, LL = lower limit, UL = upper limit.
[a] Covariance parameter estimates of the variance components were 355.71 for baseline level, 0 for change in level, 0.085 for slope, -0.12 for autocorrelation, and 88.65*** for level-1 variance.
* = $p < .05$, ** = $p < .03$, *** = $p < .01$

Table 42

Empirical Bayes (EB) PELI Vocabulary Subtest

	Baseline Level	Treatment Effect	Slope
Dyad 1	64.92	-8.25	1.33
Dyad 2	91.75	-8.25	1.50
Dyad 3	78.20	-8.25	1.35
Dyad 4	48.05	-8.25	1.40

PELI Pre- and Post Intervention Assessments

Participant's early literacy skills were assessed using the full form PELI books once at the beginning of the baseline phase and once at the end of the intervention phase. The scores on each PELI book subtest (i.e., Alphabet Knowledge, Vocabulary and Oral Language, Comprehension, and Phonological Awareness) were compared to determine if there was an increase in student's skills from the beginning to the end of the study. Additionally, the PELI Composite Score and the PELI Language Index were calculated to provide an overall estimate of the students' early literacy and language skills, respectively. No post-test data was obtained for Dyad 4, but pre-test scores are reported.

Alphabet Knowledge. Table 43 shows the percent accuracy on the Alphabet Knowledge subtest of the PELI books. It also reports students' raw scores and the beginning of the year benchmark expectation for 4-5 year old students. All three dyads were meeting benchmark expectations during the baseline phase of the study. Dyads 1 and 2 were able to identify about half of the letters presented during baseline, and both students doubled their accuracy by the end of the intervention phase. Dyad 3 had the highest accuracy during the baseline phase (92.31%), and showed a slight increase between the initial baseline and the last intervention assessment.

Table 43

Descriptive Statistics for PELI Books, Alphabet Knowledge

	Baseline Phase		Intervention Phase	
	Percent Correct	Raw Score (Beginning of Year Benchmark)	Percent Correct	Raw Score (Beginning/ End of Year Benchmark)
Dyad 1	46.15%	12 (6)	92.31%	24 (6/23)
Dyad 2	42.31%	11 (6)	92.31%	24 (6/23)
Dyad 3	92.31%	24 (6)	96.15%	25 (6/23)
Dyad 4	42.31%	11 (6)	No Scores Obtained	

Vocabulary/ Oral Language. Table 44 shows the percent accuracy on the Vocabulary/ Oral Langauge subtest of the PELI books. It also reports students' raw scores and the beginning of the year benchmark expectation for 4-5 year old students. All three dyads were exceeding benchmark expectations during the baseline phase of the study. Additionally, all three dyads showed an increase in scores from the start of the baseline phase to the end of the intervention phase. Dyad 2 had the largest increase in scores with 62.86% accuracy at the start of baseline and 82.86% accuracy at the end of intervention. Dyads 1 and 3 also showed an improvement in accuracy from baseline to intervention with an increase of approximately three percentage points for both students.

Table 44

Descriptive Statistics for PELI Books, Vocabulary/ Oral Language

	Baseline Phase		Intervention Phase	
	Percent Correct	Raw Score (Beginning of Year Benchmark)	Percent Correct	Raw Score (Beginning/ End of Year Benchmark)
Dyad 1	57.14%	20 (18)	60.00%	21 (18/23)
Dyad 2	62.86%	22 (18)	82.86%	24 (18/23)
Dyad 3	74.29%	26 (18)	77.14%	27 (18/23)
Dyad 4	45.71%	16 (18)	No Scores Obtained	

Comprehension. Table 45 shows the percent accuracy on the Comprehension subtest of the PELI books. It also reports students' raw scores and the beginning of the year benchmark expectation for 4-5 year old students. Dyads 1 and 3 were exceeding benchmark expectations during the baseline phase of the study. Dyad 2 was performing below the benchmark expectation during baseline, and showed an increase in scores with 52.17% accuracy at the start of baseline and 78.26% accuracy at the end of intervention. Dyads 1 and 3 both showed a slight decrease in scores from the start of baseline to the end of intervention. However, both students in dyads 1 and 3 appeared to be less engaged during the assessment at the end of the intervention, and needed frequent redirection to task. This may account for the decrease in scores for these students.

Table 45

Descriptive Statistics for PELI Books, Comprehension

	Baseline Phase		Intervention Phase	
	Percent Correct	Raw Score (Beginning of Year Benchmark)	Percent Correct	Raw Score (Beginning/End of Year Benchmark)
Dyad 1	73.91%	17 (13)	52.17%	12 (13/17)
Dyad 2	52.17%	12 (13)	78.26%	18 (13/17)
Dyad 3	60.86%	14 (13)	52.17%	12 (13/17)
Dyad 4	52.17%	12 (13)	No Scores Obtained	

Phonological Awareness. Table 46 shows the percent accuracy on the Phonological Awareness subtest of the PELI books. It also reports students' raw scores and the beginning of the year benchmark expectation for 4-5 year old students. All three dyads were exceeding benchmark expectations during the baseline phase of the study. Dyads 2 and 3 both showed an increase in scores from the start of baseline to the end of intervention. Dyad 1 showed a decrease in scores with baseline performance at 53.33% and intervention performance at

33.33%. During the assessment at the end of the intervention phase, the student in Dyad 1 was repeating the words presented on the phonological awareness task instead of stating the first sound in the word. The student continued with this pattern of performance even with prompting from both the examiner and the student's parent. The parent indicated during the assessment session that they had been practicing identifying the first sounds in words, and that the student knew how to perform the skill. This information indicates that the assessment score at the end of intervention may be an underestimate of the student's skills, and could account for the student's decrease in scores.

Table 46

Descriptive Statistics for PELI Books, Phonological Awareness

	Baseline Phase		Intervention Phase	
	Percent Correct	Raw Score (Beginning of Year Benchmark)	Percent Correct	Raw Score (Beginning/End of Year Benchmark)
Dyad 1	53.33%	8 (4)	33.33%	5 (4/13)
Dyad 2	46.67%	7 (4)	93.33	14 (4/13)
Dyad 3	0.00%	0 (4)	40.00%	6 (4/13)
Dyad 4	33.33%	5 (4)	No Scores Obtained	

PELI Composite Score. Table 47 shows the PELI Composite Score for the PELI books for each participant as well as the beginning of the year benchmark expectation. The composite score is a weighted score which allows all subtest scores to contribute equally to the overall score. It is also considered to be the best overall estimate of participant's early literacy skills (Dynamic Measurement Group, 2015). All three dyads were exceeding benchmark expectations during the baseline phase of the study. Dyads 2 and 3 both showed an increase in scores from the start of baseline to the end of intervention. Dyad 1 showed a decrease in scores with a baseline performance composite score of 184 and an intervention performance composite score

of 179. This is consistent with some of the previously reviewed data for Dyad 1. However, despite the decrease in composite scores for Dyad 1, the student was still performing above the expected benchmark levels.

Table 47

Descriptive Statistics for PELI Books, PELI Composite Score

	Baseline Phase		Intervention Phase	
	Composite Score	Beginning of Year Benchmark	Composite Score	Beginning/End of Year Benchmark
Dyad 1	184	159	179	159/231
Dyad 2	164	159	263	159/231
Dyad 3	182	159	203	159/231
Dyad 4	138	159	No Scores Obtained	

PELI Language Index. Table 48 shows the PELI Language Index scores for the PELI books for each participant as well as the beginning of the year benchmark expectation. The language index is a weighted score that combines student scores on the Vocabulary/ Oral Language subtest and the Comprehension subtest (Dynamic Measurement Group, 2015). All three dyads were exceeding or meeting benchmark expectations during the baseline phase of the study. Dyads 2 showed an increase in scores from the start of baseline to the end of intervention. Both Dyads 1 and 3 showed a decrease in scores from the start of baseline to the end of intervention. This is consistent with some of the previously reviewed data for Dyads 1 and 3. Dyad 3 continued to meet benchmark expectations at the end of the intervention phase despite the decrease in scores. Dyad 1 fell below the benchmark expectation at the end of the intervention phase, but was not performing below the cut point for being at risk.

Table 48

Descriptive Statistics for PELI Books, PELI Language Index

	Baseline Phase		Intervention Phase	
	Language Index	Beginning of Year Benchmark	Langauge Index	Beginning/End of Year Benchmark
Dyad 1	128	114	111	114/143
Dyad 2	114	114	159	114/143
Dyad 3	134	114	129	114/143
Dyad 4	96	114	No Scores Obtained	

Social Validity

The Shared Storybook Reading Project Rating Scale (SSRPRS) was used to measure parent's thoughts about the importance and practicality of the intervention. Parents used a five-point likert scale, ranging from one (strongly disagree) to five (strongly agree), to rate the practicality and importance of the intervention. Total scores fall between 23 and 115, with higher scores indicating higher levels of satisfaction with the shared story-book reading intervention. All three dyads completed the SSRPRS on the last day of treatment. Parents total scores ranged from 93 to 115, with a mean item score of 4.68 and a standard deviation of 0.53. This indicates that the parents participating in the study were highly satisfied with the intervention overall. When examining individual parent responses to the questionnaire, the parents in dyad-1 and dyad 2 had total scores of 115, with a mean item score of 5 and a standard deviation of 0. This is the highest rating possible on the social validity scale, which further indicates that the parents were highly satisfied with the intervention. The parent in dyad-3 had a total score of 93, with a mean item score of 4.04 and a standard deviation of 0.47. While these scores are lower than the ratings provided by the other two dyads, they do indicate that the parent answered in agreement (i.e., a rating of 4 or higher) with the majority of the questions on the scale.

Table 49

Descriptive Statistics for Shared Storybook Reading Project Rating Sale (SSRPRS)

	Social Validity Ratings	
	Total Score	Mean (SD)
Dyad 1	115	5 (0)
Dyad 2	115	5 (0)
Dyad 3	93	4.04 (0.47)

Overview

An overview of the visual analysis and HLM results is presented in Table 50.

Table 50

Overview of Results

	Visual Analysis		*Non-Overlap Statistics*			*Masked Visual Analysis*	*Hierarchical Linear Modeling*	
	Increase Level	Decrease Level	Weak	Moderate	Strong	Effect	Positive Effect	Negative Effect
eNumeracy								
Counting Arrays	2, 4	1, 3	2	4			2, 4	Average, 1, 3
Ordinal Position	2, 3	1 4= no change	4		2, 3	X*	3	Average, 1, 2, 4,
Matching Quantities to Numerals	1, 2	3, 4	1		2		Average, 1, 2, 3, 4	
Partitioning Equal Quantities	1, 2	3, 4	2	1				Average, 1, 2, 3, 4
Number Recognition	1, 2, 3, 4		3	1, 2, 4				Average, 1, 2, 3, 4
Total Math Score	1, 2, 3, 4		1, 3, 4	2			2	Average, 1, 3, 4
PELI Quick Check								
Phonological Awareness	1, 2, 3, 4			1, 3			Average, 1, 2, 3, 4	
Vocabulary/ Oral Language	1	3 2= no change	1					Average, 1, 2, 3, 4

Table 50 (Continued)

	Visual Analysis		*Non-Overlap Statistics*			*Masked Visual Analysis*	*Hierarchical Linear Modeling*	
	Increase Level	Decrease Level	Weak	Moderate	Strong	Effect	Positive Effect	Negative Effect
PELI Books								
Alphabet Knowledge	1, 2, 3		N/A			N/A	N/A	
Vocabulary/ Oral Language	1, 2, 3		N/A			N/A	N/A	
Comprehension	2	1, 3	N/A			N/A	N/A	
Phonological Awareness	2, 3	1	N/A			N/A	N/A	
PELI Composite	2, 3	1	N/A			N/A	N/A	
PELI Language Index	2	1, 3	N/A			N/A	N/A	

Note. 1 = Dyad 1; 2 = Dyad 2; 3 = Dyad 3; 4 = Dyad 4; X = Effect for Masked Visual Analysis; Average = Average Treatment Effect; N/A = Not Applicable.
* = $p < .05$

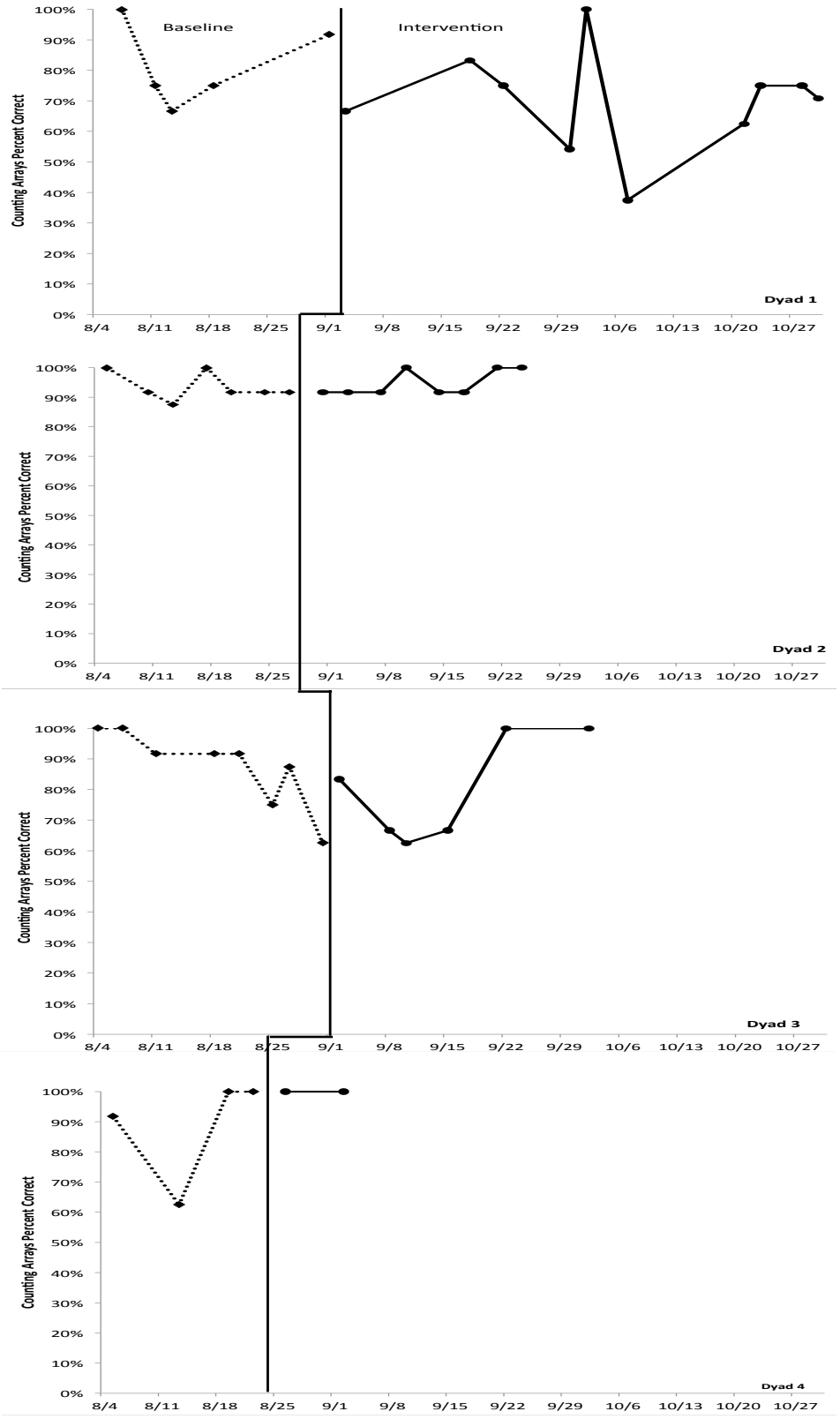

Figure 1. Multiple Baseline Results for eNumeracy, Counting Arrays Subtest

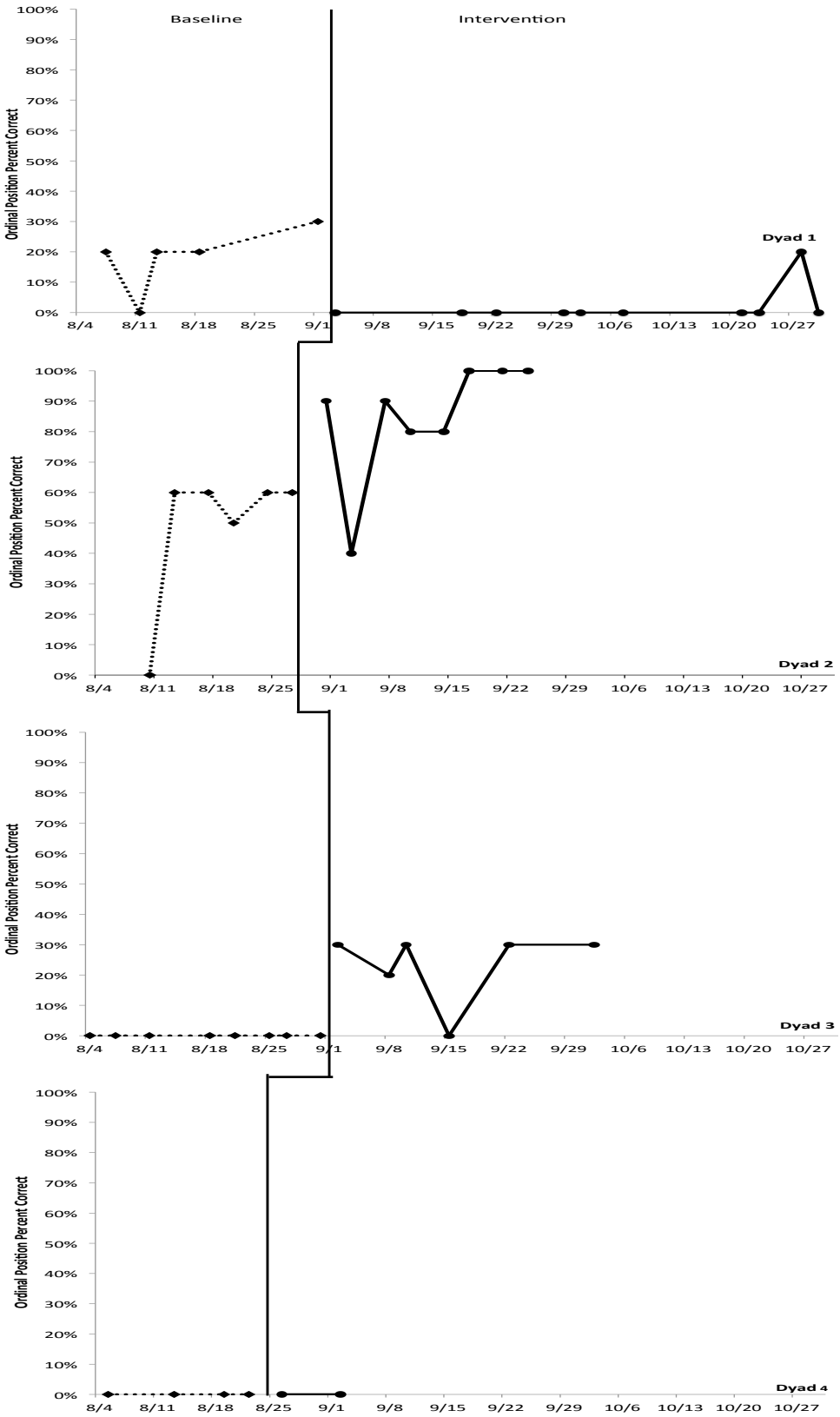

Figure 2. Multiple Baseline Results for eNumeracy, Ordinal Position Subtests

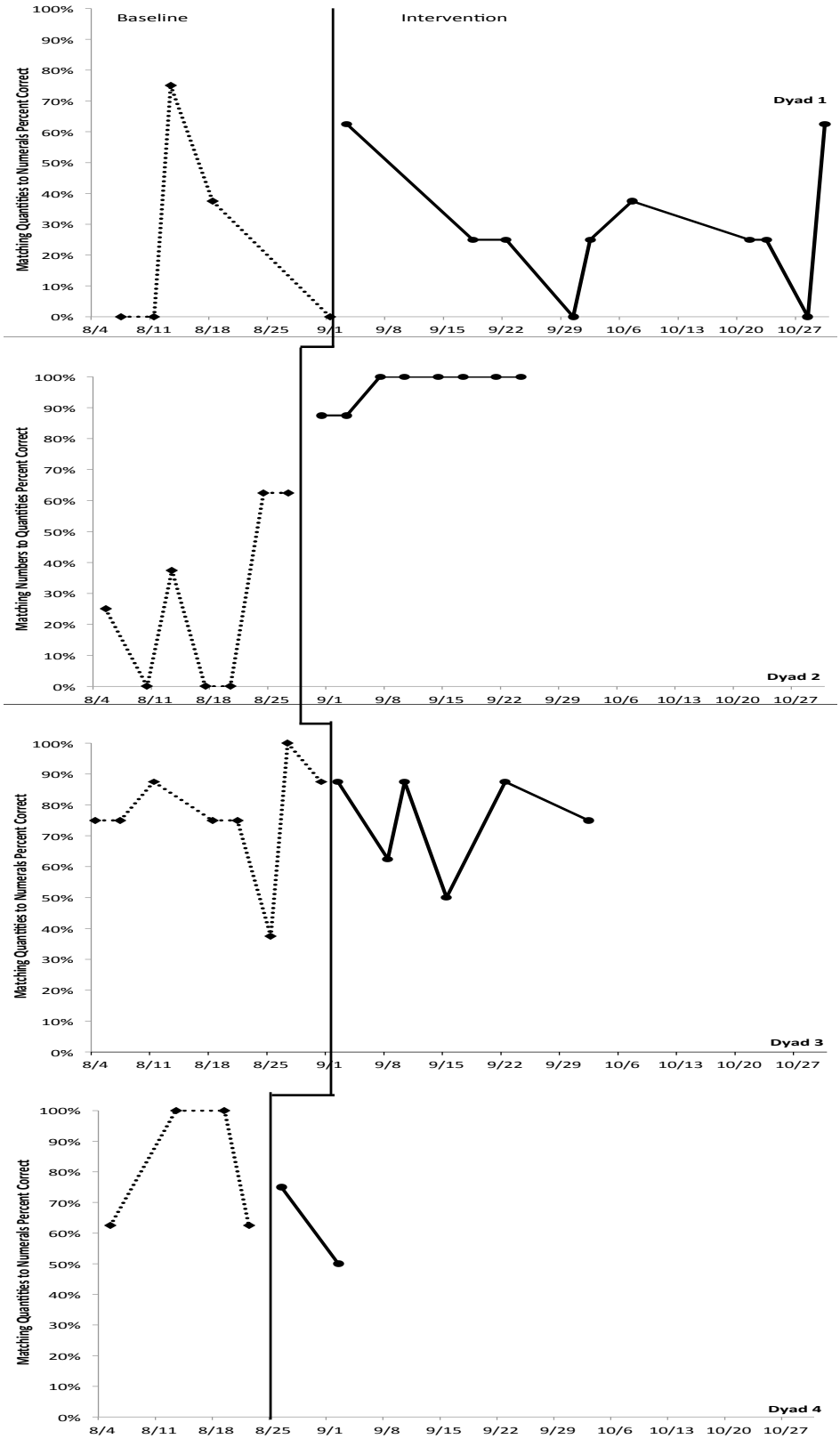

Figure 3. Multiple Baseline Results for eNumeracy, Matching Quantities to Numerals Subtests

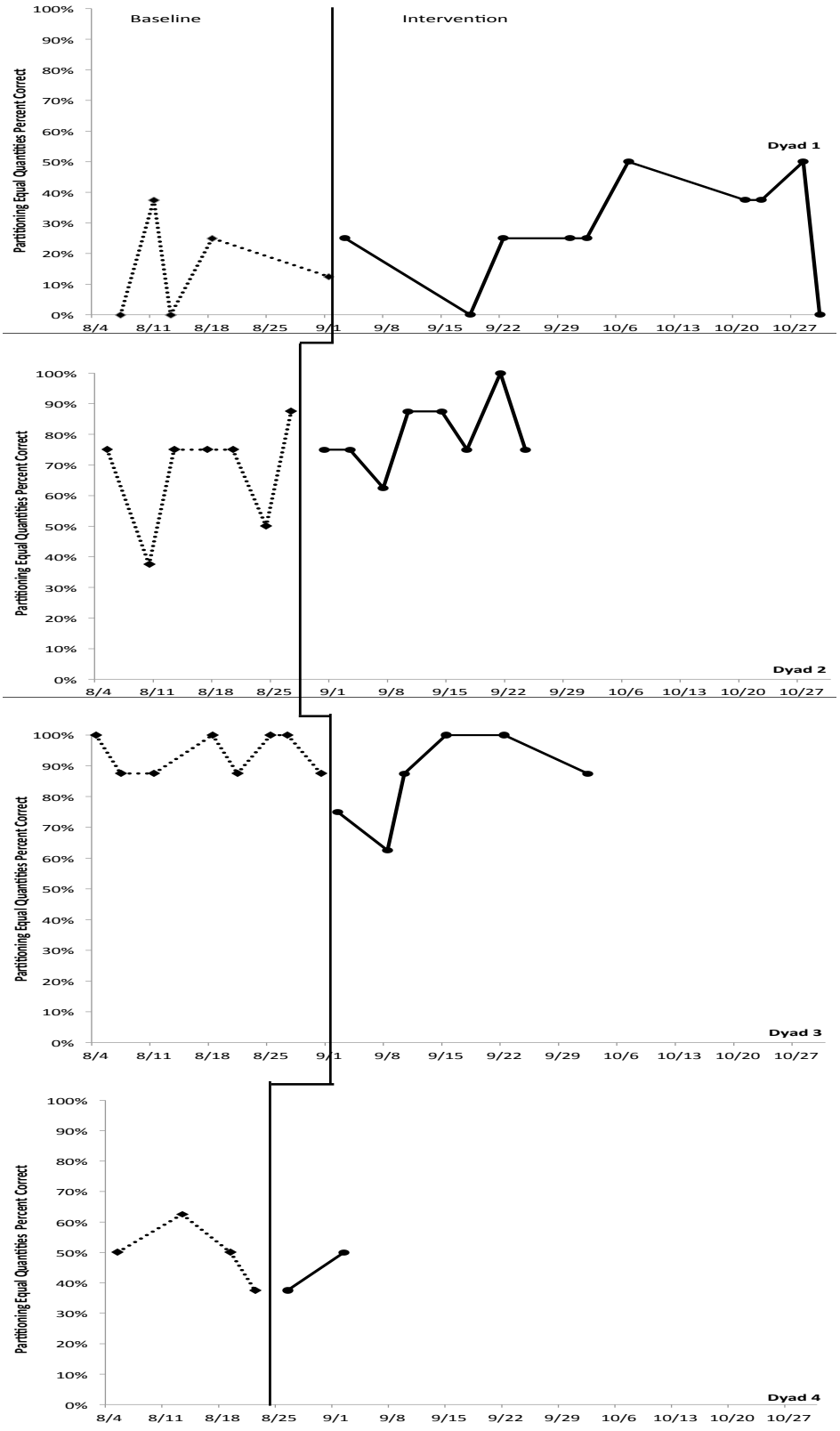

Figure 4. Multiple Baseline Results for eNumeracy, Partitioning Equal Quantities Subtests

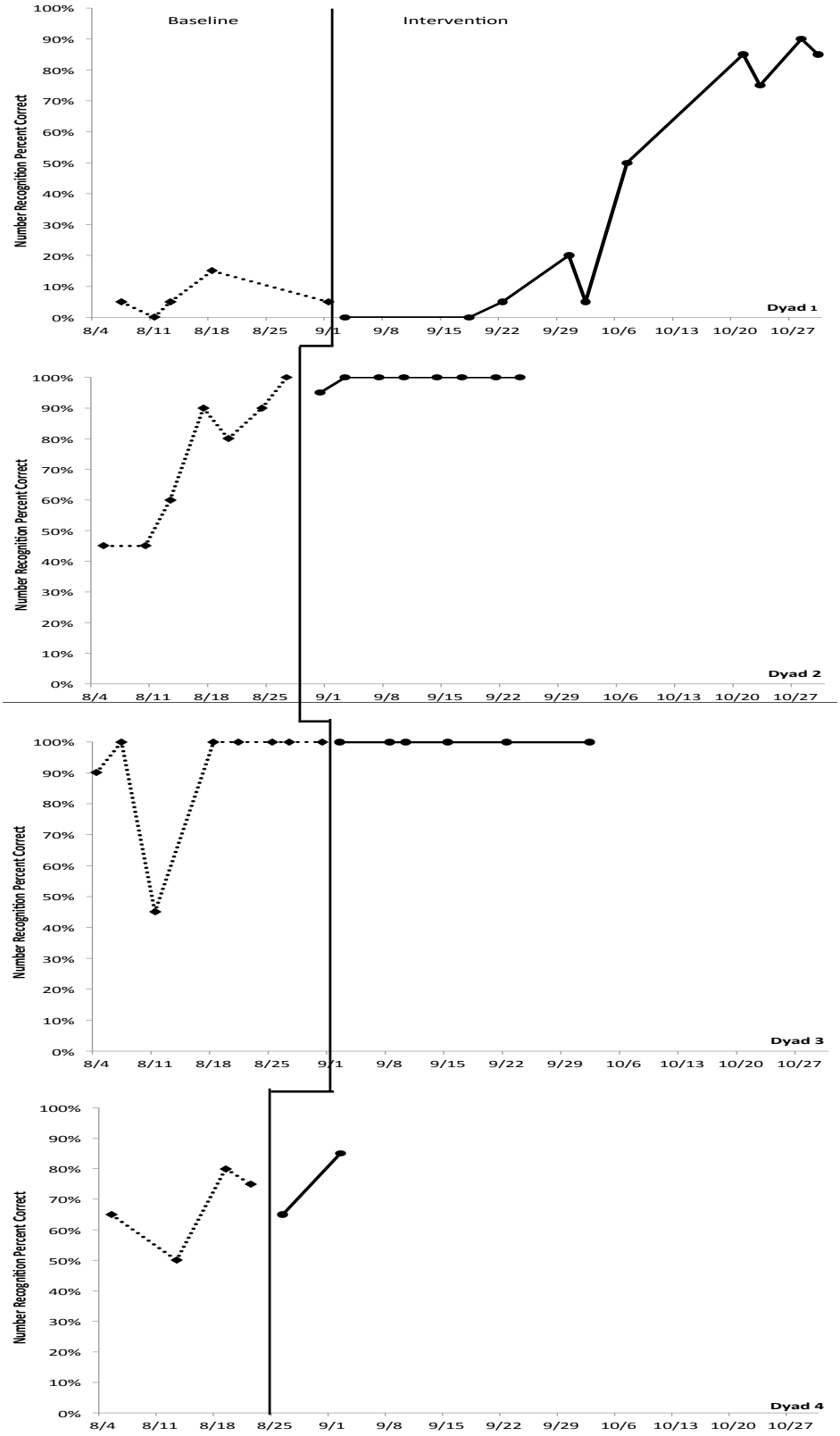

Figure 5. Multiple Baseline Results for eNumeracy, Number Recognition Subtests

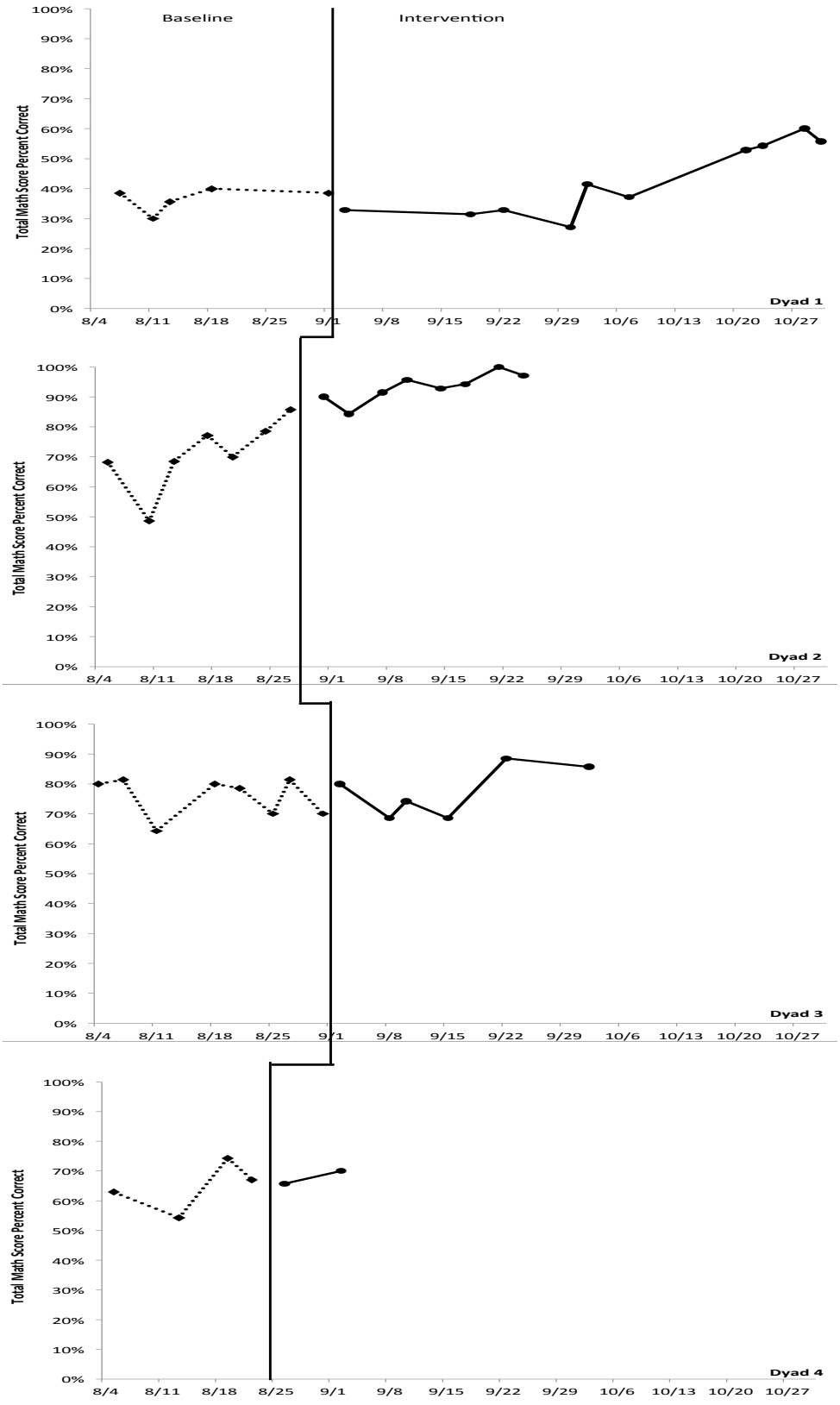

Figure 6. Multiple Baseline Results for eNumeracy, Total Math Score

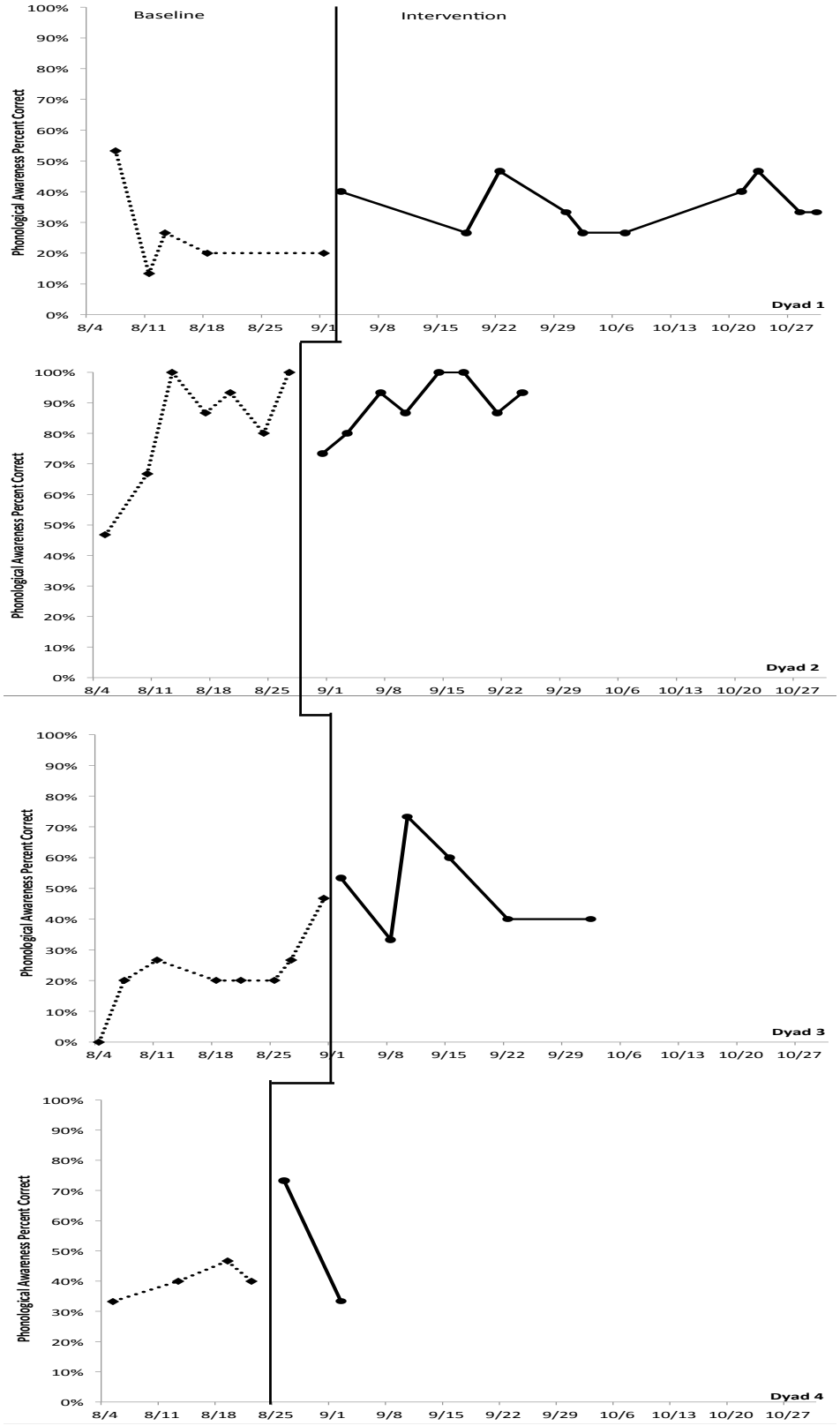

Figure 7. Multiple Baseline Results for PELI, Phonological Awareness Subtests

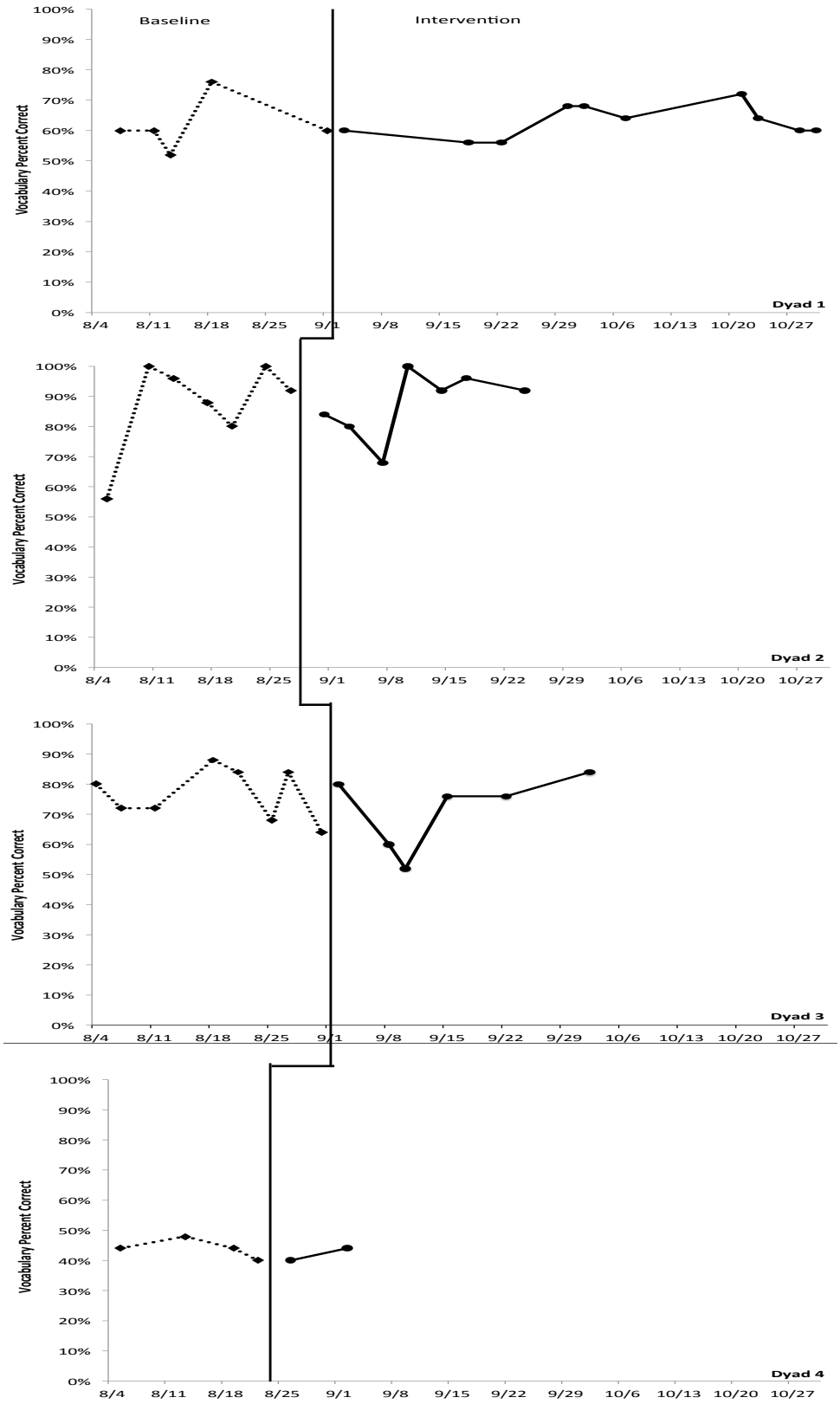

Figure 8. Multiple Baseline Results for PELI, Vocabulary Subtests

CHAPTER FIVE: DISCUSSION

Research indicates that few U.S. students are meeting high mathematical standards, and more students are performing at baseline proficiency levels when compared to the international averages (Kelly et al., 2013; National Center for Education Statistics, 2013). Children's early numeracy skills are not only predictive of later academic achievement (Duncan et. al., 2007), but they are also necessary for developing higher order mathematics and problem solving skills (Gersten & Chard, 1999). Research has also revealed that children who either engaged in early numeracy activities at home with their parents, or students who had a moderate to strong understanding of early numeracy concepts when entering kindergarten, had higher math achievement in the fourth and eighth grade (Mullis, Martin, Foy, & Arora, 2012). Although effective early numeracy interventions have been identified, few empirical studies have focused on how parents can interact with their children to help them develop early numeracy skills. Parent directed early numeracy interventions that have been examined include schools helping parents implement early numeracy interventions (Starkey & Klein, 2000), game board interventions (Ramani & Siegler, 2008; Siegler & Ramani, 2009), and storybook interventions (Hojnoski, Columba, & Polignano, 2014). Of these options, shared storybook reading is particularly promising because it incorporates both early numeracy and early literacy concepts. A previous study conducted by Hojnoski and colleagues (2014) indicates that shared mathematical storybook reading interventions can increase mathematical dialogue between parents and children, but the study did not measure children's early numeracy achievement outcomes. The purpose of the current study was to extend the work of Hojnoski and colleagues

(2014) by examining the impact of a parent directed, shared mathematical storybook reading intervention on children's early numeracy and literacy achievement.

Through the use of a non-concurrent multiple baseline design, the present study examined the impact of a parent directed, shared mathematical story book reading intervention in the following outcomes: (a) children's early numeracy skills (including cardinality, ordinality, number naming, matching numerals with quantity, and partitioning equal quantities), (b) mathematical dialogue between parents and children, (c) children's early literacy skills (including phonological awareness and vocabulary), (d) parent attitudes toward the intervention, and (e) intervention integrity. This chapter provides a discussion of the results for each research question, presents the contributions of this research to the current literature base, and provides implications for research and educational practice. Finally, the chapter concludes with a review of the limitations to the present study and future research directions.

Research Question One

The first research question assessed the degree to which a parent-led, shared mathematical storybook reading intervention increased the mathematical dialogue between parents and children (when compared to baseline observations). Mathematical dialogue was measured by coding math-talk and non-math talk in two transcriptions of parent-child reading sessions, and then calculating the amount of mathematical speech for both parents and children. Specifically, both the frequency and the percentage of math utterances were calculated for parents and children during baseline and intervention phases.

All parent-child dyads showed an increase in the number of math utterances from the baseline to intervention phase. Additionally all three dyads showed an increase in the percentage of parent mathematical dialogue, and Dyads 1 and 2 also showed an increase in the percentage of

children's mathematical dialogue. The student in dyad 3 showed a decrease in the percentage of mathematical dialogue from baseline to intervention. However, although this student had a higher percentage of mathematical dialogue during baseline, the frequency of mathematical utterances tripled during the intervention phase of the study. The large percentage of mathematical dialogue during baseline is likely explained by the small number of total utterances relative to the number of mathematical utterances in the transcribed storybook reading session. This suggests that, although there was a high ratio of mathematical to non-mathematical dialogue during baseline, there was an increase in mathematical dialogue for the student in Dyad 3 based on the increased number of mathematical utterances. The findings from this study are consistent with the previous study conducted by Hojnoski and colleagues (2014) regarding the impact of shared math storybook reading on parent-child mathematical dialogue.

Research Question Two

The second research question asked to what degree would a parent-led intervention improve children's early numeracy skills (e.g., cardinality, ordinality, number naming, matching numerals with quantity, and partitioning equal quantities). Children's early numeracy skills were measured through the eNumeracy: Early Math Assessment subtests including Counting Arrays, Ordinal Position, Matching Numerals to Quantities, Partitioning Equal Quantities, and Number Recognition. Additionally, students math scores on the five eNumeracy subtests were added together each week to calculate their Total Math score.

Counting Arrays

Data analysis for the eNumeracy Counting Arrays subtest indicated that there were a decrease in performance for Dyads 1 and 3, and an increase in performance for Dyads 2 and 4 over time. These data were consistent across visual analysis, effect sizes, and multi-level

modeling. Specifically, there was a decrease in mean level from baseline to intervention for Dyads 1 and 3, and negative treatment effects. Dyads 2 and 4 showed increases in mean level from baseline to intervention and a positive treatment effect. However, none of the participants' data were statistically significant. Additionally, all dyads showed weak to moderate non-parametric effect sizes. The masked visual analysis also showed no effect of the intervention on students' skills. Overall, these findings suggest that the intervention had no effect on children's cardinality skills.

Ordinal Position

Results for the eNumeracy Ordinal Position subtest showed that there was a decrease in performance for Dyad 1 across analyses, and increases in performance for Dyads 2 and 3 over time based on visual analyses. Dyad 4 showed no change in performance from baseline to intervention phases across statistical analyses. In contrast, Dyad 2 showed a negative treatment effect when examining the multi-level model results, which indicates that the actual treatment effect was lower than the expected treatment effect based on the trend in baseline data for Dyad 2. While none of the treatment effects based on the multi-level model were statistically significant, the masked visual analysis showed a significant effect from treatment for dyads 1, 2 and 3. Overall, there was a noticeable change in student performance from baseline to intervention for all participants that completed the study. However, for dyad 1 this change was in the opposite direction of anticipated treatment effects. Behavioral observations of the student during the assessment sessions suggest that the student in dyad 1 was guessing on the Ordinal Position tasks, and this may have lead to falsely inflated scores during the baseline assessment sessions.

Overall, the results indicate that there was a noticeable, but not a statistically significant, change in performance on the Ordinal Position tasks for students that completed the study. Additionally, these results are inconclusive because not all student's demonstrated a change in performance that was consistent with the expected direction of treatment effects.

Matching Quantities to Numerals

Data for the eNumeracy Matching Quantities to Numerals subtest showed that there was a slight decrease in performance for Dyads 3 and 4, and increases in performance for Dyads 1 and 2 over time based on the visual analyses and non-overlap statistics. In contrast, all dyads demonstrated a positive effect from treatment when examining the multi-level modeling effect sizes. This discrepancy in results across the different analyses is likely occurring because only the multi-level model considers the trend in data when calculating treatment effects. The treatment effects for Dyads 3 and 4 indicate that the student's performance in the intervention phase was higher than the projected performance based on the trend in baseline. The multi-level model results were not statistically significant for any of the participants. The masked visual analysis also showed no observable treatment effects. Overall, these findings suggest that the intervention had no effect on children's performance on the eNumeracy Matching Quantities to Numerals subtest.

Partitioning Equal Quantities

Test results for the eNumeracy Partitioning Equal Quantities subtest showed that there was a slight decrease in performance for Dyads 3 and 4, and increases in performance for Dyads 1 and 2 over time based on the visual analyses and non-overlap statistics. However, all four dyads showed a decrease in effect sizes based on multi-level modeling analyses. This indicates that the actual treatment effect was lower than the expected treatment effect based on the trend in

baseline data for Dyads 1 and 2. None of the treatment effects based on the multi-level model were statistically significant. In addition, masked visual analyses showed no observable effects for participants' skills in this domain. Overall, these findings suggest that the intervention had no effect on children's performance on the eNumeracy Partitioning Equal Quantities subtest.

Number Recognition

Data analysis for the eNumeracy Number Recognition subtest indicated increases in performance across all participants. Specifically, all dyads showed an increase in mean level from baseline to intervention phase and positive non-overlap statistics. In contrast, all dyads showed a negative treatment effect based on the results of the multi-level model analysis. This indicates that the actual treatment effects were lower than the expected treatment effect based on the trend in baseline data across participants. While multi-level model treatment effects were not statistically significant, the slope was statistically significant. This indicates that student's performance significantly increased over time. Although it is possible that the increase in slope was due to the intervention, the current study did not examine if there was a change in slope between the baseline and intervention phases due to the age of the students in the study. Therefore it is not possible to determine if the significant increase in student performance over time was due to the intervention or other confounding variables (e.g., starting kindergarten, maturation, etc.). Masked visual analysis indicated no observable effects for this measure. Overall, these findings suggest that the intervention had no effect on children's performance on the eNumeracy Number Recognition subtest.

eNumeracy Total Math Score

Results for the eNumeracy Total Math score showed that there were increases in performance for all dyads over time based on visual analyses and non-overlap statistics.

However, treatment effects based on the multi-level model were negative for Dyads 1, 3 and 4. This indicates that the actual treatment effect is lower than the expected treatment effect based on the trend in baseline data for Dyads 1,3 and 4. Dyad 2 showed a positive treatment effect based on multi-level model analysis. None of the multi-level model results were statistically significant. Additionally, the masked visual analysis showed no observable effects for participants skills in this domain. Overall, these findings suggest that the intervention had no effect on children's overall early numeracy performance.

While previous studies suggest that mathematical dialogue between parents and children is related to children's early numeracy performance, no empirical studies have been conducted to specifically examine this relationship. Hypotheses have been generated regarding the lack of statistically significant increases in children's early numeracy skills based on the current intervention. One potential hypothesis pertains to the research design of previously conducted studies. Specifically, studies conducted by Levine and colleagues (2010), and Gunderson and Levine (2010) showed that increased mathematical dialogue between parents and children (ages 14-30 months), was positively related to children's performance on a cardinality task at 46 months of age. Results indicated that this relationship was present even when controlling for socioeconomic status and non-mathematical dialogue. However, the previous research did not control for children's initial mathematical, developmental or cognitive levels when conducting these studies. It is possible that parents whose children have more advanced development between 14 and 30 months of age are more likely to engage in mathematical dialogue with their children. Similarly, it is possible that children with higher levels of performance on the cardinality task at 46 months, also had more advanced early numeracy skills between 14 and 30 months of age.

Another hypothesis pertains to the types of assessments completed in the current study compared to previous research. The current study examined a broad array of children's early numeracy skills including cardinality, ordinal position, matching numerals with quantities, number recognition, and partitioning quantities. Previous research conducted has only examined the impact of parent-child mathematical dialogue on children's cardinality skills using the "Point to X task" (Gunderson & Levine, 2011; Levine, et al., 2010; Wynn, 1992a). Children were presented with two arrays of squares, ranging from one to six, and the children were required to point to the array that matched a verbally presented number (Gunderson & Levine, 2011; Levine, et al., 2010; Wynn, 1992). While children's accuracy was greater on the "Point to X task" in previous studies when parents engaged their children in more mathematical dialogue, it is possible that the measures used in the current study were not sensitive enough to detect changes in children's skills. Specifically, the measures used in the current study may not have aligned well with the skills being practiced during the parent-child mathematical dialogue. Although the reading guides used in the current study targeted some specific skills on which the students were assessed, such as ordinal numbers and comparing quantities, overall the reading guides covered a variety of different early numeracy topics. It may be beneficial for future research to focus more on a few specific skills throughout the reading guides to see if explicit practice with fewer early numeracy topics produces larger gains in children's skills.

An additional hypothesis relates to the age of the students, and the amount of time that passes between the parent-child mathematical dialogue exposure and the assessments. First, the students in previous studies were much younger during parent-child mathematical dialogue activities with students ranging in age from 14 to 30 months (Gunderson & Levine, 2011; Levine, et al., 2010). The students enrolled in the current study were all five years of age. It is

possible that children need to be exposed to mathematical dialogue at an earlier age in order for it to have an impact on their mathematical performance. In addition, the amount of time between the parent-child mathematical dialogue and the time of assessment was much greater in previous studies (Gunderson & Levine, 2011; Levine, et al., 2010). Specifically, parent-child mathematical dialogue was measured between 14 and 30 months of age, but children's cardinality skills were not measured until the children were 46 months of age. This suggests that the impact of parent-child mathematical dialogue on children's early numeracy skills may not happen immediately, but may occur after additional time has passed.

Finally, previous research suggests that the type of parent-child mathematical dialogue can have an impact on children's mathematical skills. Specifically, Gunderson and Levine (2011) found that parents' mathematical dialogue that includes counting or identifying groups of objects that are present and visible have more of an impact on children's later mathematical performance when compared to mathematical dialogue that does not meet these criteria. Additionally, mathematical dialogue that refers to larger sets of items (i.e., sets ranging from four to ten items) leads to greater mathematical achievement than other types of mathematical dialogue (Gunderson & Levine, 2011; Levine, et al., 2010). It is possible that no significant effects were observed for children's mathematical achievement in the present study because the mathematical dialogue between parents and children needed to be more focused on counting and identifying large sets of items that were visible in the pictures.

Research Question 3

The third research question examined to what degree a parent-led, shared math book reading intervention improved children's early literacy skills (e.g., phonological awareness and vocabulary). Children's early literacy skills were measured using the Preschool

Early Literacy Indicators (PELI). Specifically, the PELI books were used once at the beginning of baseline and again at the end of intervention as a form of pre- and post-test measure of children's overall early literacy skills. Additionally, students' phonological awareness and vocabulary/ oral language skills were measured twice a week throughout the baseline and intervention phases of the study using the PELI Quick Check measures for these specific skills.

Descriptive statistics from the PELI pre- and post-test measures indicated that most of children's early literacy scores increased from the assessments at the beginning of baseline to the end of intervention. Students showed an increase in percent accuracy and raw scores, across all participants, for Alphabet Knowledge and Vocabulary/ Oral Language measures. Dyad 2 also showed an increase in performance on the Comprehension, Phonological Awareness, PELI Composite, and PELI Language measures. Dyads 1 showed decreases on all additional measures, and Dyad 3 showed decreases on the Comprehension and PELI Language Index and increases on the Phonological Awareness and PELI Composite measures.

Data analysis of the PELI Quick Check measures indicated that all dyads showed an increase in Phonological Awareness and no change or a decrease in Vocabulary/ Oral Language skills. Results from visual analysis, effect sizes, and multi-level modeling showed an increase in all participants in Phonological awareness skills. However, this increase was not statistically significant. For Vocabulary/ Oral Language, visual analysis indicated minimal to no changes in scores for Dyads 1 and 2, and a decrease in scores for Dyad 3. HLM results indicate a decrease in treatment effect for all participants, but the change was not statistically significant. Additionally, the HLM model did not provide individual Empirical Bayes estimates for participants, which indicates that HLM model was not able to effectively differentiate individual treatment effects from the average treatment effect. The inconsistencies between the visual

analyses and HLM results are likely due to the HLM model allowing for trend in the data. The negative treatment effect indicates that the actual treatment effect is lower than the expected level based on the trend in baseline data.

Overall, these findings are inconclusive regarding whether or not shared mathematical storybook reading between parents and children increases vocabulary and phonological awareness skills. Previous studies indicate that dialogic reading strategies increase children's vocabulary skills but not their phonological awareness (Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988). Because the current study used a modified version of dialogic reading, children were expected to show increases in their vocabulary skills but not phonological awareness. It is possible that the measures used to assess children's skills throughout the study were not aligned to the skills and vocabulary the children learned throughout the intervention. Some of the vocabulary measures used in previous studies were targeted more toward children's receptive vocabulary skills (e.g., had child identify a picture that matches a specific word) or less complex expressive vocabulary skills (e.g., had child name a picture) compared to the measures used in the current study (What Works Clearinghouse, 2007). Previous studies also used the *Illinois Test of Psycholinguistic Abilities – Verbal Expression Subscale* (ITPA-VE; Kirk, McCarthy, & Kirk, 1968) which measured children's verbal fluency. In contrast, the PELI Vocabulary/ Oral Language measure required students to not only describe a verbally presented word, but students also received additional points for using correct and more complex grammatical structures. It is possible that a measure with more of a focus on expressive or

receptive vocabulary fluency without the grammar component would have shown a greater increase in children's overall vocabulary scores.

Research Question 4

The fourth research question examined parents' ratings of intervention acceptability. The Shared Storybook Reading Project Rating Scale (SSRPRS) was used to measure parent's thoughts about the importance and practicality of the intervention.

The results from the SSRPRS indicate that parents found the interventions effective and practical for working with their children on early numeracy skills. Dyads 1 and 2 showed the highest levels of intervention satisfaction, and indicated high levels of agreement (i.e., item scores equal to 5) on all items on the rating scale. Dyad 3 showed the greatest variability in item scores, with ratings ranging from slight disagreement (i.e., item scores equal to 3) to high agreement (i.e., item scores equal to 5). Specifically, Dyad 3 indicated slight disagreement (i.e., item scores equal to 3) when asked if "the activities used in the project were easy to complete" and if "activities fit well into the kinds of activities my child and I like to do together." However, Dyad 3 indicated agreement or high levels of agreement for all additional items on the SSRPRS, suggesting that the parent was still satisfied with most aspects of the intervention. Additionally, all parents indicated high levels of agreement (i.e., item scores equal to 5) for the following statements: 1) "participation in this project was effective in supporting my child's mathematical development," 2) "this project was a good way to promote early mathematical skill development at home," and 3) "overall, participation in the project was beneficial for my child." Overall, these results suggest that parents who completed the study were satisfied with the intervention. These results are similar to those found by Hojnoski and colleagues (2014). However, it should be noted that one participant dropped out before the end of the study for

unknown reasons. It is possible that the feedback from this parent would have been different from those participants who successfully completed the study.

An additional hypothesis pertaining to the high levels of parent satisfaction with the intervention used in the current study relates to parent beliefs about children's early numeracy and early literacy skills. Previous research indicates that parents typically think of children's early literacy skills as more important than early numeracy skills (Cannon & Ginsburg, 2008; Ramani et al., 2011; Sonnenschein, et al., 2012). Incorporating both early literacy and early numeracy concepts into the same intervention may have made the intervention more acceptable to parents than an intervention focusing completely on children' early numeracy skills.

Finally, it should be noted that parents reported high levels of social validity even though the student outcome measures indicated that the intervention had little effect on student's skills. This discrepancy could be due to parents observing growth in their students numeracy skills over the course of the study that were not reflected in the weekly assessment sessions. Additionally, all parents of students participating in the study were present during their child's assessment sessions. The examiners did not give student's feedback on their answers to assessment questions, but instead gave praise for hard work. It is possible that parents interpreted the examiner's praise of student's effort as indicating the child provided accurate answers. Several parents also noted that they read with their students every night anyway, and enjoyed access to the additional reading material. This could also have contributed to the high levels of social validity.

Research Question 5

The final research question analyzed the degree of intervention integrity parents used when implementing the shared math storybook reading intervention with their children.

Intervention integrity was evaluated by (a) calculating the percent of reading guides completed by parents each week, and (b) calculating the percent agreement between the parent and primary investigator regarding the reading guide steps completed for one week.

The results from the percentage of reading guides completed show that there was a high rate of overall intervention fidelity. Dyads 1, 2, and 3 completed the reading guides for the majority of the reading sessions with the percentage of steps completed ranging from 61% to 100%. Dyad 4 only completed two weeks of intervention prior to dropping out of the study, and only returned one set of reading guides. Additionally, Dyad 4 only completed 33% of the reading guides.

The percent agreement between the parent and primary investigator regarding the reading guide steps completed for one week was also examined for Dyads 1, 2, and 3. No audio recordings were returned from Dyad 4 so no additional intervention integrity data was available. Results showed that there was 100% agreement between Dyads 2 and 3 and the primary investigator regarding the reading guide steps completed. In contrast, there was 0% agreement between the primary investigator and Dyad 1. While the parent in Dyad 1 did incorporate extra-textual dialogue into the shared reading sessions, none of the steps on the reading guides were completed. There are several possible reasons that could explain the lower levels of intervention integrity for Dyads 1 and 4 compared to the other study participants. First, Dyad 1 took the longest to complete the study due to scheduling conflicts and needing to reschedule many of the assessment sessions. Similarly, Dyad 4 dropped out of the study early due to unknown reasons. It is possible that Dyads 1 and 4 did not have as much time to devote to participation in the intervention activities, and decided to simply incorporate mathematical dialogue instead of completing the reading guides as they were designed. It is also possible that Dyads 1 and 4

needed additional training to implement the reading guides as planned. While these dyads were able to implement the reading guides as planned during the training session with the primary investigator, the parents may have benefitted from additional training or follow-up regarding how to implement the interventions and fill-out the reading guides. Finally, Dyad 4 only completed one set of reading guides and did not return any audio recordings, which resulted in a smaller sample of data to analyze regarding intervention integrity compared to other participants. It is possible that Dyad 4 completed more of the reading guides than they indicated on the forms. Overall, half of participants were able to implement the interventions with high rates of fidelity. This is consistent with previous research that suggests parent training and monitoring procedures increase the fidelity of intervention implementation (Hook & DuPaul, 1999; Persampieri, Gortmaker, Daly, Sheridan, & McCurdy, 2006; Powell-Smith, Stoner, Shinn, & Good, 2000; Sterling-Turner, Watson, Wildmon, Watkins, & Little, 2001).

Contributions to the Literature

The results of the current study extend upon the limited research literature related to parent directed early numeracy interventions. Previous studies have shown that there is a connection between parent-child mathematical storybook reading and the increase of parent-child mathematical dialogue (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013), and that mathematical dialogue can increase children's early numeracy skills (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). The current study demonstrated an increase in mathematical dialogue between all parent-child dyads, which is consistent with results in the prior research literature (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard,

2008; Van den Heuvel-Panhuizen & Elia, 2013). However, there was not a statistically significant increase in children's early numeracy skills for any of the measures used. Previous studies show that parent-child mathematical dialogue is related to children's later mathematical outcomes, but did not measure children's initial developmental levels or mathematical achievement which could also account for the relationship between parent-child mathematical dialogue and children's later mathematical achievement (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). The children in previous studies were also younger than the children enrolled in the present study, and their early numeracy skills were assessed several months after their engaging in parent-child mathematical dialogue (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). These results may suggest that children need to engage in mathematical dialogue at a younger age than in the present study in order to see positive effects on their achievement. It could also suggest that there is not an immediate impact of parent-child mathematical dialogue on children's mathematical skills. In addition, previous studies only assessed children's counting and cardinality skills (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006), whereas the current study measured a variety of early numeracy skills. It is possible that parent-child mathematical dialogue is only effective in increasing cardinality and counting skills, or that the measures used in the current study were not specific enough to detect significant changes in children's skills. Finally, previous studies suggest that specific types of mathematical dialogue are more robust predictors of children's later mathematical achievement (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006). It is possible that no significant effects were observed for children's mathematical achievement in the present study because the mathematical dialogue between parents and

children was not targeted towards these specific criteria. This was not measured in the current study.

In addition to measuring mathematical dialogue and children's early numeracy skills, this study investigated if applying dialogic reading to mathematical storybook reading would increase children's early literacy skills. Previous research has shown positive literacy outcomes when using dialogic reading (Lonigan et al.,1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988), but has not examined the impact of applying dialogic reading to mathematical storybooks. The current findings showed no statistically significant increases for children's phonological awareness or vocabulary skills. While children's vocabulary was expected to improve, it is possible that the measures used to assess children's skills throughout the study were not aligned to the skills and vocabulary children learned during the intervention. Additionally, previous studies used measures of vocabulary that did not account for students' grammatical structures (Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988). This could also account for the differences in findings from the current study and previous research. An additional hypothesis regarding the lack of change in children's vocabulary skills pertains to the length of the study. Previous research examining the impact of dialogic reading on children's vocabulary skills indicates that dialogic reading interventions were effective after four to six weeks of treatment (Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988).

However, in the current study, children were not only exposed to vocabulary during dialogic reading sessions but were also exposed to mathematical concepts. Because the focus of the intervention was targeting both vocabulary and mathematical concepts, children may have needed exposure to the treatment for a longer period of time in order to improve their vocabulary skills. It is also possible that the reading guides needed to incorporate more discussion pertaining to vocabulary, in addition to mathematical dialogue, in order to increase children's skills in this area.

Implications for Research and Practice

The present study illustrates that a shared patent-child mathematical storybook reading intervention did not lead to statistically significant increases in children's early numeracy or early literacy skills. It may be that certain adaptations or modifications were needed to increase the effectiveness of the current intervention. First, the measures of early literacy and early numeracy used in the current study were different than the measures used in previous research linking mathematical dialogue with children's early numeracy achievement (Gunderson & Levine, 2011; Levine et al., 2010; Suriyakham et al., 2006) and dialogic reading with children's early literacy achievement (Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Lonigan, & Whitehurst, 1998; Wasik, & Bond, 2001; What Works Clearinghouse, 2007; Whitehurst, Arnold, et al., 1994; Whitehurst, Epstein, et al., 1994; Whitehurst, et al., 1988). It is possible that with different assessment tools, targeted specifically toward the early numeracy skills and vocabulary that children encountered in the storybooks, there would have been a greater increase in children's skills over time. Specifically, researchers may want to consider targeting one or two specific mathematical skills throughout the intervention to determine if mathematical storybooks and dialogue can increase discrete early numeracy skills. It may also be beneficial to use a more

narrow vocabulary measure, targeted towards children's receptive and expressive language skills, to determine if there is an impact on children's early literacy skills. In addition, providing children with additional exposure to treatment or examining long term outcomes may provide additional insight into the effectiveness of shared mathematical storybook reading between parents and children.

The findings from the present study also indicate that the shared parent-child mathematical storybook reading intervention was effective in increasing mathematical dialogue between parents and children from baseline to intervention. This is similar to the findings from previous research (Anderson et al., 2004; Anderson et al., 2005; Flevares & Schiff, 2014; Hojnoski et al., 2014; Van den Heuvel-Panhuizen & Boogard, 2008; Van den Heuvel-Panhuizen & Elia, 2013). However the present research did not show an increase in children's early numeracy skills despite the increase in mathematical dialogue between parents and children. Previous research shows that parent child mathematical dialogue that includes counting or labeling large sets of objects (i.e., ranging from at least four to ten items), that are visibly present is a more robust predictor of children's later mathematical achievement when compared to mathematical dialogue that does not meet this criteria (Gunderson & Levine, 2011). Researchers may want to consider helping parents incorporate mathematical dialogue that is specifically targeted towards these criteria to see if it leads to a greater increase in children's early numeracy skills.

Additionally, the current study showed that the intervention was implemented with integrity by most participants. However, the parents in the study never received feedback on their implementation of the intervention after the initial training session. Additionally, the transcriptions of the shared storybook reading sessions revealed that parents often read the

dialogue exactly as it appeared on the reading guides. This occasionally led to lost opportunities to give their child feedback on early numeracy concepts. In future studies, it may be beneficial to provide additional training and feedback to parents throughout the intervention to help them continue to develop their abilities to incorporate early numeracy concepts into the reading sessions. Hojnoski and colleagues (2014) also used generalization probes at different times throughout the study to measure mathematical dialogue when parents were not provided with a reading guide. Future studies may want to implement generalization probes as well and then provide parents with frequent feedback regarding additional techniques they could use to enhance mathematical dialogue with their child.

Finally, the current study showed high ratings by parents of intervention acceptability and practicality. This is consistent with both research from similar studies (Hojnoski, et al., 2014) and hypotheses from the current study. Given the importance of parental involvement both in the home and the school settings this may be a good activity to recommend to parents of preschool and kindergarten aged students who wish to be more involved.

Limitations of the Present Study and Future Directions

The current study has noted limitations that must be considered when interpreting the results. These limitations are discussed in detail and future directions for research are presented.

First, the generalizability of the results is limited due to the specific population being examined, and the intentionally small sample size. Although four families initially enrolled in the study, one dropped out shortly after starting the intervention phase. This poses a limitation to the current study because limited early literacy and numeracy results were obtained from this student. Additionally, the family that dropped out did not provide feedback on satisfaction with the intervention. Similarly, the small sample size may have prevented accurate estimation and

detection of treatment effects using the multi-level modeling. Additionally, the present study included only five-year-old students recruited from VPK classrooms in a local school district. However, research examining the impact of shared mathematical storybook reading interventions on children's early numeracy and literacy skills is limited, therefore the current study provides important information relative to this specific population. Future studies should be conducted that include larger sample sizes in order to provided additional information on the effectiveness of shared mathematical storybook reading interventions on children's early numeracy and early literacy skills.

An additional limitation to the current study was only a small sample of mathematical dialogue was measured throughout the intervention. Sampling methods used in the current study to measure mathematical dialogue are similar to those used previously in the research literature (Boonen et al., 2011; Klibanoff et al., 2006). However, the small sample of mathematical dialogue could be an under or over representative sample of mathematical dialogue across the study. Future studies should continue to examine the impact of share storybook reading interventions on parent-child mathematical dialogue.

Furthermore, while the PELI Quick Check measures and the eNumeracy Early Math Assessment were designed specifically for preschool students, there is no reliability and validity data available for these measures. It is possible that the measures used in the current study are not related to the measures used in previous studies indicating a positive effect of parent-child mathematical dialogue on children's early numeracy skills and dialogic reading on children's early literacy skills. Additionally, there was great variability in assessment scores for students throughout both the intervention and baseline phases of the study. This could have been due to differences in difficulty across the different forms of the eNumeracy and PELI subtests. Future

studies should continue to examine the impact of shared parent-child mathematical storybook reading interventions on children's early numeracy and literacy skills. Few measures are currently available that allow for repeated measures of students early numeracy and literacy skills. Research is needed to develop additional assessments examining children's early numeracy and literacy skills that can be repeated over time. Additional research examining the reliability and validity of the existing measures is also warranted.

In addition, the PELI and eNumeracy measures used were written to measure preschool students early literacy and numeracy skills respectively. However, the sample of children participating in the current study were exiting pre-school and entering kindergarten at the time of study enrollment. This could have confounding effects on the intervention in two ways. First, the children may have shown ceiling effects on the PELI and eNumeracy measures, which could result in a lack of statistically significant results. Many of the children received very high scores on the assessment measures before the start of the intervention suggesting that ceiling effects may have been present. This was especially noticeable on the Counting Arrays subtest on the eNumeracy Assessments because three of the four students received a score of 100% during the initial assessment administered. Future research should target either a younger sample of students or use assessment measures created for an older population of students to avoid ceiling effects. Additionally, all students participating in the study started kindergarten at about the same time as the intervention phase of the study started. This makes it difficult to distinguish whether the student increases in performance were due to the shared mathematical storybook reading intervention or the start of kindergarten. Future studies should continue to examine the effects of shared mathematical storybook reading between parents and children while controlling for confounding factors. Finally, when conducting assessments with young students, it is expected

to see variability in assessment scores. In future research, it may be better to administer more than one probe from each assessment to establish a more stable score for participants. This could be done by administering three probes for each assessment and then using the median score, or by averaging the data from the two weekly assessment sessions to get one data point per week. Both of these methods could lead to more stability in student assessment scores.

Finally, selecting intervention start points before establishing stable baselines may also pose as a limitation to the study. A modified version of Kratochwill and colleagues (2010) recommendations for visual analysis of single case data was used in order to prevent any family from spending an excessive amount of time in baseline. Specifically, the number of baseline reading sessions was predetermined for each dyad instead of waiting for a stable baseline to be established. This may have been problematic due to the young age of the students enrolled in the study and the anticipated variability in student performance given their young age. However, each dyad had a minimum of 5 baseline data points, which meets the recommendations set out by WWC (Kratochwill et al., 2010). Additionally, given the expectation that children's skills will increase over time, establishing a stable baseline may not be feasible. In future research, it may be beneficial to allow for longer intervention and baseline phases as well as longer staggers between participants entering the intervention phase. This would provide additional time to establish a more stable baseline and more data in each intervention phase to examine participants' response to the intervention.

Conclusions

There is need for research to identify parent directed early numeracy interventions that help improve children's mathematical achievement. Children's early numeracy skills are not only predictive of later academic achievement (Duncan et. al., 2007), but they are also necessary

for developing higher order mathematics and problem solving skills (Gersten & Chard, 1999). Research indicates that few U.S. students are meeting high mathematical standards, and more students are performing at baseline proficiency levels when compared to the international averages (Kelly et al., 2013; National Center for Education Statistics, 2013), which makes it important to target children's mathematical development at a young age. The results of the current study indicate that a shared mathematical storybook reading intervention between parents and children did not result in statistically significant improvements in children's early numeracy or literacy skills, but did show increases in mathematical dialogue between parents and children. Further research is needed in this area to determine additional methods for parents to support children's early numeracy development.

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APPENDICES

Appendix A: Parent Recruitment Flyer

Preschool Mathematical Storybook Research Study

The Preschool Math Storybook Study is an opportunity for you to help your preschool student practice their mathematical skills through reading storybooks. The study is being conducted by students at the University of South Florida to see how reading math storybooks impacts children's mathematical skills development. If you want to participate, you will be asked to attend a 1 hour training at a location that will be convenient for you (i.e., your child's school, your home, the University of South Florida). Once you participate in the training, you will be asked to do the early mathematical activities for 15-20 minutes a day, 3 days a week with your child at home. The study will last for 7 weeks. In addition to doing the mathematical activity with you, your child will engage in brief preschool math and reading assessments, 2 times a week for approximately 2 months.

By participating in this study, you will:

1. Be able to choose 10 of the storybooks included in the study to keep.
2. Your child will receive a small prize each week after completing assessments.
3. You will gain skills in making storybook reading a more fun and engaging activity for you and your child!

If you have any questions about this study please feel free to contact either:

Christy Lindahl, M.A.	or	Julia Ogg, Ph.D.
Phone: 404-625-9666		Phone: 813-974-3246
Email: clindahl@mail.usf.edu		Email: jogg@usf.edu

If you are interested in participating, please fill out the information below and return to your child's teacher.

Your Name: _____

Your Child's Name: _____

Best Phone Number to Reach You: _____

Additional Phone Number(s) where you can be reached:

_____

_____

Email: _____

Appendix B: Consent Form

Parental Permission to Participate in Research Involving Minimal Risk

Information for parents to consider before allowing their child to take part in this research study

IRB Study # Pro00021088

The following information is being presented to help you and your child decide whether or not your child wishes to be a part of a research study. Please read this information carefully. If you have any questions or if you do not understand the information, we encourage you to ask the researcher.

We are asking you to allow your child to take part in a research study called:
Developing Early Numeracy Skills in Preschool Children Through a Shared Parent/Child Book Reading Intervention

The person who is in charge of this research study is Christy Lindahl. This person is called the Principal Investigator. However, other research staff may be involved and can act on behalf of the person in charge. She is being guided in this research by Dr. Julia Ogg.

The research will be conducted at your child's school. Additionally, you will be asked to complete research activities with your child at home, and to meet with the Principal Investigator, at a location convenient for you, to learn how to conduct the research activities with your child.

Purposeof study: why is this research being done?

We need to learn more about how parents can help their children improve their early mathematical skills! The interventions we will be using have been effective in engaging parents and preschool children in mathematical dialogue and activities at home. The information that we collect from students may help increase our awareness of how parents can help their children improve their mathematical skills. It is not certain that participating in this study will improve your child's skills.

Why is your child being asked to take part?

We are asking your child to take part in this research study because of his or her enrollment in a Voluntary Pre-Kindergarten (VPK) program in Pasco County School District. We want to find

out more about how a shared storybook reading intervention impacts preschool children's early numeracy skills. Six additional children and their parents will also be asked to participate in this study.

Study Procedures: What will happen during this study?
If your child takes part in this study, you and your child will be asked to:

- Participate in a 90 minute training provided by the Primary Investigator at a location that will be convenient for you (i.e., your child's school, your home, the University of South Florida).
- Complete the early mathematical activities for 15-20 minutes a day, 3 days a week, and to audio record each of these reading sessions. The intervention period will last 7 weeks.
- In addition to doing the mathematical activities with you, your child will engage in brief early numeracy skills assessments, 2 times a week for approximately 4 months. These tests will require that your child name numbers, count objects, match numbers with the correct set of objects, name the order of objects (e.g., first, second, third, etc.), and to decide if two characters received an equal share of objects for the Primary Investigator. The assessments will take less than 20 minutes per session, and will take place in the VPK classroom during regular school hours.

Total Number of Participants
About 6 parents and their children will take part in this study at USF.

Alternatives / Voluntary Participation / Withdrawal

If you decide not to let your child take part in this study, that is okay.
You should only let your child take part in this study if both of you want to. You or child should not feel that there is any pressure to take part in the study to please the study investigator or the research staff.

If you decide not to let your child take part:

- Your child will not be in trouble or lose any rights he/she would normally have.
- Instead of being in this research study you can choose not to let your child participate.
- Your decision to participate, not to participate, or to withdraw participation at any point during the study will in no way affect your child's student status, his or her grades, or your relationship with VPK, USF, or any other party.

You can decide after signing this informed consent form that you no longer want your child to take part in this study. We will keep you informed of any new developments which might affect your willingness to allow your child to continue to participate in the study. However, you can decide you want your child to stop taking part in the study for any reason at any time. If you decide you want your child to stop taking part in the study, tell the study staff as soon as you can.

Benefits: what are the potential benefits to your child if you let him / her take part in this study?
The potential benefits to your child include:

- Participation in the study has the potential to increase both children's' skills in early numeracy and literacy, and parents' knowledge regarding the importance of early numeracy, dialogic reading, and how to engage their children in mathematical dialogue.
- Additionally, the knowledge gathered from the results of the study can help inform parent directed interventions in the future.

Risks or Discomfort: what are the risks if your child takes part in this study?

There are no known risks to those who take part in this study.

Compensation: will your child be compensated for taking part in this study?

You and your child will be able to choose one children's book included in the study to keep each week, and will receive an additional three books at the end of the study (for a total of 10 books). In addition, your child will be provided with a small toy at the end of each week. If you withdraw your child for any reason from the study before completion, your child will receive one book for every week that he/she participated ***(i.e., if you participate for 5 weeks, you will receive 5 books).***

What will it cost you to let your child take part in this study?

It *will not* cost you *anything* to let your child take part in the study.

Privacy and Confidentiality

We will keep your child's study records private and confidential. Certain people may need to see your child's study records. By law, anyone who looks at your child's records must keep them completely confidential. The only people who will be allowed to see these records are:

- The research team, including the Principal Investigator, study coordinator, and all other research staff**.**
- Certain government and university people who need to know more about the study. For example, individuals who provide oversight on this study may need to look at your child's records. This is done to make sure that we are doing the study in the right way. They also need to make sure that we are protecting your child's rights and his/her safety.
- Any agency of the federal, state, or local government that regulates this research. This includes the Department of Health and Human Services (DHHS) and the Office for Human Research Protection (OHRP).
- The USF Institutional Review Board (IRB) and its related staff who have oversight responsibilities for this study, staff in the USF Office of Research and Innovation, USF Division of Research Integrity and Compliance, and other USF offices who oversee this research.

We may publish what we learn from this study. If we do, we will not include your child's name. We will not publish anything that would let people know who your child is.

You can get the answers to your questions, concerns, or complaints.

If you have any questions, concerns or complaints about this study, call Christy Lindahl at (404) 625-9666.

If you have questions about your child's rights, general questions, or have complaints, concerns or issues you want to discuss with someone outside the research, call the USF IRB at (813) 974-5638.

Consent for My Child to Participate in this Research Study

It is up to you to decide whether you want your child to take part in this study. If you want your child to take part, please read the statements below and sign the form if the statements are true.

I freely give my consent to let my child take part in this study. I understand that by signing this form I am agreeing to let my child take part in research. I have received a copy of this form to take with me.

_____ _____

Signature of Parent of Child Taking Part in Study Date

_____

Printed Name of Parent of Child Taking Part in Study

Statement of Person Obtaining Informed Consent

I have carefully explained to the parent of the child taking part in the study what he or she can expect from their child's participation. I hereby certify that when this person signs this form, to the best of my knowledge, he/ she understands:

- What the study is about;
- What procedures will be used;
- What the potential benefits might be; and
- What the known risks might be.

I can confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in the appropriate language. Additionally, this subject reads well enough to understand this document or, if not, this person is able to hear and understand when the form is read to him or her. The parent signing this form does not have a medical/psychological problem that would compromise comprehension and therefore make it hard to understand what is being explained and can, therefore, give legally effective informed consent. The parent signing this form is not under any type of anesthesia or analgesic that may

cloud their judgment or make it hard to understand what is being explained and, therefore, can be considered competent to give permission to allow their child to participate in this research study.

_____ _____

Signature of Person Obtaining Informed Consent Date

_____

Printed Name of Person Obtaining Informed Consent

Appendix C: Demographic Questionnaire

Demographic Questionnaire

Student Information

Student Name _____ **School Name_____**

Student's Date of Birth_____

1. **Student's Gender**
   ❍ 1. Male ❍ 2. Female

2. **Student's Ethnicity**
   ❍ 1. African American/Black ❍ 4. Hispanic
   ❍ 2. Asian/ Pacific Islander ❍ 5. Native American/ Alaska Native
   ❍ 3. White ❍ 6. Other (Specify _____)

3. **Student's Age** ❍ 4 ❍ 5

Parent/ Guardian Information

Name_____

Relation to Student_____

Gender
❍ 1. Male ❍ 2. Female

Ethnicity
❍ Check here if parent/ guardian ethnicity is the same as the student
❍ 1. African American/Black ❍ 4. Hispanic
❍ 2. Asian/ Pacific Islander ❍ 5. Native American/ Alaska Native
❍ 3. White ❍ 6. Other (Specify _____)

Marital Status
❍ 1. Married ❍ 3. Divorced
❍ 2. Single ❍ 4. Other (Specify _____)

Highest Level of Education Obtained
❍ High school ❍ Associates Degree
❍Bachelor's Degree ❍Master's Degree
❍Other Advanced Degree (Specify _____)

Home Phone: _____

Cell Phone: _____

Work Phone: _____

Email: _____

Please note that all information <u>will be kept confidential,</u> and any contact information provided will only be used to contact you regarding participation in this specific study.

Appendix D: Storybook List

Book	**Author**
Ten Flashing Fireflies	By Philemon Sturges & Anna Vojtech
Over in the Meadow	By Olive A. Wadsworth
Feast for 10	By Cathryn Falwell
One big building: A counting book about construction	By Michael Dahl
Monster Musical Chairs	By Stuart Murphy
The twelve days of summer	By Jan Andrews
Just a Piggy Bank	By Gina & Mercer Mayer
Quack and Count	By Keith Baker
Henry the Fourth	By Stuart Murphy
Two ways to count to 10: A Liberian Folktale	By Dee, R. (1988)
Five Little Monkeys Jumping on the Bed	By Eileen Christelow
Fish Eyes: A Book You Can Count on	By Lois Ehlert
One is a snail, 10 is a crab: A counting by feet book	By April Pulley Sayre
Ten little Fish	By Audrey Wood
How do you count a dozen ducklings?	By In Seon Chae and Seung Ha Rew
The Button Box	By Margarette S. Reid
Centipede's 100 Shoes	By Tony Ross
Grandma's Button Box	By Linda Williams Aber
A Chair for My Mother	By Vera B. Williams
Rooster's Off to See the World	By Eric Carle
How many snails? A counting book	By Giganti, Paul, Jr. and Donald Crews
Ten Black Dots	By Donald Crews
One Hungry Monster	By Susan Heyboer O'Keefe
Mouse Count	By Ellen Stoll Walsh
Swimmy	By Leo Lionni
Equal Shmequal	By Virginia Kroll and Philomena O'Neill
The Seven Chinese Sisters	By Kathy Tucker
Ten, Nine, Eight	By Molly Bang
Balancing Act	By Ellen Stoll Walsh
Raindrop, plop!	By Wendy Cheyette Lewison

Appendix E: Phone Screening Script

Greet caregiver and introduce yourself:

Hello. My name is _____. Thank you for volunteering to participate in this eligibility screening for this study entitled "Developing Early Numeracy Skills in Preschool Children Through a Shared Parent/Child Book Reading Intervention." I'm a _____ in the _____ program at the University of South Florida. Today I'll be asking you some questions to learn a little bit more about you and your child, and answering any questions you may have about the study. This will ensure that you know what the study entails and that you and your child are a good fit for the study.

Just to give you a sense of what this project is all about, we are interested in exploring discussions about math or "math talk" between parents and children during shared storybook reading and its effect on children's "math talk" and early math knowledge.

All information discussed will be confidential. You may refuse to answer any question and stop this interview at anytime. I will begin with the questions, would you like to continue?

Questions

1. ***What is your relationship to the child that will be participating?***
    a. ***Are you above the age of 18?***
2. ***How old is your child?***

Child should be between the ages of 4 and 5.

3. ***Where does your child go to school?***
4. ***Are there any languages other than English spoken in the home?***
    a. ***If yes, does your child speak both languages?***
    b. ***Is your child fluent in English?***
    c. ***Are you comfortable reading storybooks in English to your child?***

Parent must answer yes to questions 3b and 3c to participate.

5. ***Has your child ever been diagnosed with one of the following?***
    a. ***Intellectual Disability?***
    b. ***Developmental Delay?***
    c. ***Language Impairment?***
    d. ***Deafness?***
    e. ***Blindness?***
    f. ***Autism?***

If the parent answers yes to any part of question 4, they are not eligible to participate in the study.

6. ***Has your student ever been enrolled in an Exceptional Student Education program?***

a. If yes, what program is your child enrolled in?

If child is receiving special education services for InD, DD, LI, or ASD they are not eligible to participate in the study.

7. *During this study, you will be given 3 math books to read with your child every week for a total of 7 weeks. Due to the nature of this study, we highly recommend that parents read these books on three different days throughout each week. Do you think this will be feasible for you and your child?*

If the parent says yes "as long as nothing major comes up in a given week" reassure them that we understand that sometimes things change. If they can't read the books on three separate days, we ask them to try to read the books at different times during the day (i.e., don't read all three in one sitting) and to make a note of it on the study materials.

If the parent says no they can't read the books on three separate days or at different times during the day (i.e., don't read all three in one sitting), then they are not eligible to participate in the study.

If child is eligible to participate:

Thank you so much for taking the time to talk with me and answer these questions. If you are still interested in participating, it sounds like you and your child would be a great fit for this study. Do you have any further questions about the study? If you later decide you have any questions, please contact the research team at (404) 625-9666, or (813) 974-3246. Thank you. Someone from the study will be in touch with you soon so that we can schedule a time to meet and go over procedures for the first part of the study. Thank you again for your interest, and we look forward to working with you!

If child is NOT eligible to participate:

Thank you so much for taking the time to talk with me and answer these questions. Based on the responses you gave, it sounds like this study may not be the right fit. We are looking for typically developing students between ages of 4 and 5 that are fluent in English. We really appreciate your interest in our study though, and we wish you and your child the best as he/she moves forward in school. Because you are not eligible to participate in this study, we will destroy the data collected during this phone interview to protect your confidentiality. Thank you again for your time!

Screener's Notes:

Appendix F: Book Reading Survey (Baseline Phase)

Name: _____ Date:_____

Book Reading Survey

Insert Name of Specific Book Here

Instructions: Please audio record you and your child reading this storybook and fill in the following information:

Date that you and your child first read the book: _____

How many more times after the initial reading did you re-read the book? 0 1 2 3 >4

Appendix G: Recruitment Flyer for School Principals

Recruitment Flyer for School Principals

Preschool Mathematical Storybook Research Study

The Preschool Math Storybook Study is an opportunity for parents to help their preschool students practice their mathematical skills through reading storybooks. The study is being conducted by students at the University of South Florida to see how reading math storybooks impacts children's mathematical skills development. If parents want to participate, they will be asked to attend a 1 hour training at a location convenient for them (i.e., child's school, their home, the University of South Florida). Once they participate in the training, they will be asked to do the early mathematical activities for 15-20 minutes a day, 3 days a week with their child at home. The study will last for 7 weeks. In addition to doing the mathematical activity with their child, the child will engage in brief preschool math and reading assessments, 2 times a week for approximately 2 months.

Benefits to Parents/Children for Participating:

1. Parents will gain skills in making storybook reading a more fun and engaging activity for you and your child!
2. Children's early numeracy and literacy skills may increase as a result of participating in the study.

Benefits to the School/District for Participating:

1. Participation in the study has the potential to increase both children's' skills in early numeracy and literacy, and parents' knowledge regarding the importance of early numeracy, dialogic reading, and how to engage their children in mathematical dialogue.
2. The knowledge gathered from the results of the study can help inform parent directed interventions in the future, and increase parental involvement.

Participant Compensation:

1. Parents/children will be able to choose 10 of the storybooks included in the study to keep.
2. The child will receive a small prize each week after completing assessments.

If you have any questions about this study please feel free to contact either:

Christy Lindahl, M.A.
Phone: 404-625-9666
Email: clindahl@mail.usf.edu

or

Julia Ogg, Ph.D.
Phone: 813-974-3246
Email: jogg@usf.edu

Appendix H: Consent to Audio Record

IRB Study # _____Pro00021088_____

CONSENT FOR AUDIO TAPING AND THE RETENTION OF AUDIO TAPES

I, _____, freely consent to allow the audiotaping of the eNumeracy and PELI
(Your Name)

subtests with all members of the research team and my child _____,
(Your Child's Name)

during the remainder of the study. This audiotape may be retained for the duration of the study,

for the purpose of scoring the assessments, conducting inter-observer agreement, and training

members of the research team on the assessment scoring procedures. Audiotapes cannot be used

for any other purpose or in any other location without my written consent. I understand that I am

free to withdraw my consent for taping and retention of audiotapes at any time.

Consent for My Child to be Audiotaped in this Research Study

It is up to you to decide whether you want your child to be audiotaped during the assessment sessions. If you agree to let your child be audiotaped, please read the statements below and sign the form if the statements are true.

I freely give my consent to let my child be audiotaped during the eNumeracy and PELI subtests. I understand that by signing this form I am agreeing to let my child be audiotaped as part of the research study. I have received a copy of this form to take with me.

_____ _____

Signature of Parent of Child Taking Part in Study Date

_____

Printed Name of Parent of Child Taking Part in Study

Statement of Person Obtaining Informed Consent

I have carefully explained to the parent of the child taking part in the study what he or she can expect by agreeing to let their child be audiotaped during the eNumeracy and PELI subtests. I hereby certify that when this person signs this form, to the best of my knowledge, he/ she understands:

- What will be audiotaped;
- What the audio recordings will be used for; and
- The duration of time that the audio recordings will be retained.

I can confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in the appropriate language. Additionally, this subject reads well enough to understand this document or, if not, this person is able to hear and understand when the form is read to him or her. The parent signing this form does not have a medical/psychological problem that would compromise comprehension and therefore make it hard to understand what is being explained and can, therefore, give legally effective informed consent. The parent signing this form is not under any type of anesthesia or analgesic that may cloud their judgment or make it hard to understand what is being explained and, therefore, can be considered competent to give permission to allow their child to participate in this research study.

_____ _____

Signature of Person Obtaining Informed Consent Date

_____

Printed Name of Person Obtaining Informed Consent

Appendix I: IRR Letter of Approval

USF
UNIVERSITY OF
SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-7091

3/30/2015

Christina Lindahl, B.S.
Educational and Psychological Studies
4202 E. Fowler Ave.
Tampa, FL 33620

RE: **Expedited Approval for Initial Review**
IRB#: Pro00021088
Title: Developing Early Numeracy Skills in Preschool Children Through a Shared Parent/Child Book Reading Intervention

Study Approval Period: 3/27/2015 to 3/27/2016

Dear Ms. Lindahl:

On 3/27/2015, the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents outlined below.

Approved Item(s):
Protocol Document(s):
Lindahl Final Thesis Proposal

Consent/Assent Document(s)*:
Parental Permission.pdf

Consent/Assent Script(s)
Recruitment Phone Screening Script

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR

56.110. The research proposed in this study is categorized under the following expedited review category:

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The screening portion of your study qualifies for a waiver of the requirements for the documentation of informed consent as outlined in the federal regulations at 45CFR46.117(c) which states that an IRB may waive the requirement for the investigator to obtain a signed consent form for some or all subjects if it finds either: (1) That the only record linking the subject and the research would be the consent document and the principal risk would be potential harm resulting from a breach of confidentiality. Each subject will be asked whether the subject wants documentation linking the subject with the research, and the subject's wishes will govern; or (2) That the research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context.

Per CFR 45 Part 46, Subpart D, this research involving children was approved under the minimal risk category 45 CFR 46.404: Research not involving greater than minimal risk.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

Kristen Salomon, Ph.D., Vice Chairperson
USF Institutional Review Board