GAME BASED INTERVENTION TO DEVELOP EARLY CHILDHOOD MATHEMATICAL UNDERSTANDING AND DECREASE GAPS RELATED TO SOCIOECONOMIC STATUS

by

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ABSTRACT

Early mathematical understanding is important for later success in mathematics. Game based interventions can be a successful means by which to help young students to improve their mathematical understandings. The purpose of this study is to examine whether a math game that was to be played at home improved the mathematical understanding of kindergarten students. Kindergarten students, from rural Idaho, were assigned to a group that played math games (n = 15) or a control group that did not (n = 13). The intervention group was given a simple math game and instructed to play 20 times in a 2 week period. The control group played a sight word game with the same instructions for frequency. Results showed that playing the game at home did not improve performance on the math assessment. A survey was also used to gather information about whether or not reported amounts of game playing at home would be correlated to higher scores on a mathematics assessment. Results showed that reported game playing at home was not related to higher scores on a mathematics assessment.

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CHAPTER ONE: STATEMENT OF PROBLEM

I have taught elementary school for eight years. Most of that time has been spent teaching third-grade students. In third-grade one of the expectations is that students are expected to add and subtract three-digit numbers fluently. Year after year I struggled to teach this concept to many of my students. Some students entered third-grade able to perform this task, some able to add and subtract large numbers in their heads. Others struggled the entire year to solve these problems. Problems in context proved especially difficult.

I noticed that this ability was not evenly distributed throughout the class. The students living in poverty were much more likely to be struggling not only to add and subtract but more likely to be generally struggling in mathematics. I began to use number sense warm ups each day to try to build number sense. I discovered that many of the students could not count by 10. Even fewer students could count by 10 if they had to start at a number other than zero. Many of the students struggled to count from 99 to 101. I realized that the problem was not the addition and subtraction concept; the problem was that they had few of the skills needed to support addition and subtraction. But, how could I, in one year, teach them all of the supporting skills and teach them the third-grade concepts so that they would be ready for fourth grade? It seemed an impossible task.

A decade into my teaching career I began to tutor a former student who was struggling in middle school math. It quickly became obvious that the problem that I had always found so frustrating in third-grade was only exacerbated in middle school math.

This student, despite a strong desire to do well, could not keep up with the class because she lacked basic number sense. She performed the long division algorithm when she needed to divide by 10 and set up the standard subtraction algorithm to subtract a one-digit number from a two-digit number. Each problem was a struggle, because for her, no step was simple.

I wanted to do something to build math skills in students at a younger age. I also wanted to find something that would be fun for the kids, and I did not have a lot of extra time to devote to anything. So, I began a math game club in the mornings before school. Students who were struggling in math in first grade would play math games with students struggling with math in third and fourth grade. The club was a huge success. Not only did the children love to come to the club each morning but their teachers reported that they were making gains in class.

I had learned that the number sense problems that I had seen in third-grade were not isolated to third-grade, rather, they became more troublesome as students advanced in school. I had also seen that playing games seemed to be an effective intervention. But, this was all anecdotal.

This is why I have chosen to do a literature review on whether research supports the idea that early mathematical understandings are vital for later success, whether socioeconomic status is an exceptionally strong predictor of mathematical understanding, and whether there is research that supports the idea that math games could be an effective intervention for students struggling in mathematics. These questions led me to the problem that I attempted to address in my study. Students from low socioeconomic backgrounds are more likely to struggle in math when they reach elementary school

(Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). Students who struggle in mathematics early on are likely to struggle in mathematics throughout their schooling (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). While there are some interventions that have been shown to be effective, when I considered how we might replicate them in my school I determined that many of these interventions were too expensive or difficult to implement in a public school without additional funding. I will consider whether game playing at home will influence performance on a math assessment.

The research questions are the following:

Research Question #1

Will change in performance on a mathematics assessment be influenced by playing a math game at home?

Research Question #2

Will students from low socioeconomic backgrounds improve their math scores more than students from high socioeconomic backgrounds after playing a math game at home?

Research Question #3

Is initial math performance related to parent-reported home learning activities?

Specifically, my main research question is whether playing a math game at home will influence performance on a mathematics assessment. I will also consider whether students from low socioeconomic backgrounds improve their math scores more than students from high socioeconomic backgrounds after playing a math game at home.

Finally, I will consider whether math performance is related to the amount of game playing at home.

CHAPTER TWO: LITERATURE REVIEW

Game Based Intervention to Develop Early Childhood Mathematical Understanding and Decrease Gaps Related to Socioeconomic Status

Mathematical understanding demonstrated in kindergarten and first grade are predictive of students' later mathematical abilities (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). It is therefore important to identify which specific mathematical ideas are most important for later success and which children are the most likely to struggle to meet grade level benchmarks. Research has specifically found that counting and numeracy (Aunio & Niemivirta, 2010; Aunola et al., 2004; Nelson & McMaster, 2019; Nguyen et al., 2016), general number sense (Geary et al., 2007; Jordan et al., 2007), and spatial reasoning are predictive of later mathematics achievement (Holmes et al., 2008; Lauer & Lourenco, 2016; Lowrie et al., 2016). Students from low socioeconomic backgrounds are at increased risk for beginning their schooling deficient in mathematical understanding (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). With the understanding that early mathematical understanding is vital for later success and that students from low socioeconomic backgrounds are at heightened risk of low achievement in kindergarten and first grade it is important to turn our attention to what we know about solutions for these students. A vital piece of information as we consider this puzzle is that the home numeracy environment is an important piece to deciphering the understandings regarding mathematics that students develop (LeFevre et al., 2009; Ramani et al., 2015, Galindo & Sonnenschein, 2015; Levine et al., 2010; Yildiz et al., 2018).

With the understanding that mathematical knowledge at an early age is crucial for later success in mathematics, and that both socioeconomic status and the quality and quantity of the home numeracy environment will play a role in those understandings, we turn our attention to how we might intercede to improve outcomes for all students. Interventions can be effective in mediating this problem (Nelson & McMaster, 2019; Mononen et al., 2014). There has been research considering a wide variety of types of interventions and their success. Of specific interest to this paper is the research that has been conducted utilizing math games as a way to improve mathematics achievement. Much of this research has demonstrated promising results (Baroody et al., 2009; Griffin, 2004; Ramani & Siegler, 2008; Whyte & Bull, 2008; Wilson et al., 2009). Given what we have previously discussed regarding the home environment, it is also important to consider interventions that specifically address numeracy in the home environment. A number of studies have demonstrated that interventions targeting the home environment can be successful (Berkowitz et al., 2015; Starkey et al., 2004). Finally, of specific interest in this paper are interventions that took place in the home environment and involved games. These studies have found that game based interventions that occur in the home can be beneficial to students (Niklas et al., 2016; Ramani & Scalise, 2020; Sonnenschein et al., 2016).

This paper is organized into four main sections. The first describes the research that informs our understanding of why early childhood mathematics understanding is important and the specific elements of mathematics that are the most important. The second section describes the research surrounding socioeconomic status and achievement. This section highlights the challenges that face children growing up in low socioeconomic situations. The third section describes the current research regarding the home environment and mathematics understanding. Finally, the fourth section describes the research surrounding interventions meant to build mathematical understanding. Of particular interest are studies that have either taken place in the home environment or have utilized games as an intervention.

Early Childhood Number Understanding and Math Achievement

Students' mathematical skills in kindergarten and first grade are predictive of their later mathematical abilities (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). In a longitudinal study aimed at studying this predictive relationship Jordan et al. (2009) tested 196 students 11 times between kindergarten and third-grade. They found that higher kindergarten number competence predicted statistically significant mathematics achievement at the end of third-grade. They also found that kindergarten mathematics competence was a significant predictor of rate of achievement between kindergarten and third-grade (Jordan, et al., 2009). Claessens and Engel (2013) found similar results. In a longitudinal study considering the relationship between school entry mathematics and later success in mathematics they found that children's early math skills were more important predictors of later success than early language skills or reading skills (Claessens & Engel, 2013). The authors were interested in a variety of measures of later success in school. They used data from the Early Childhood Longitudinal Study–Kindergarten (ECLS-K). This data set included children who were in kindergarten in the 1998-99 school year (Claessens & Engel, 2013). A variety of measures were used in the fall and spring of kindergarten and spring of first, third, fifth, and eighth grades. The measures included math and reading assessment, and, beginning in third-grade, science assessments. There were interviews with parents and teacher surveys. The authors also looked at grade retention, teacher rated achievement, and a wide range of family and home characteristics. There was complete data for 7,655 children (Claessens & Engel, 2013). The most striking finding was that what they termed Math Proficiency Level 2, which measured the ability to read all one-digit numerals, count beyond 10, recognize a sequence of patterns, and use nonstandard units of length to compare objects, was the most consistent predictor of later achievement in both reading and math in elementary school and eighth grade math achievement and teacher rated achievement (Claessens & Engel, 2013).

In a longitudinal study considering the relationship between first grade early mathematics skills and third-grade math achievement as measured by a state mathematics test as well as two other hypotheses related to that relationship Kiss et al. (2019) studied 175 students from two suburban school districts in the midwest. In the study, skill specific mathematics measures were administered individually when the students were in first grade, and in third-grade the students took the state mandated assessment. (Kiss et al., 2019). The result that most closely related to the intent of this paper is that a below proficient score on the third-grade state assessment was significantly linked to low scores across all of the skills assessed in first grade, on average (Kiss et al., 2019). The authors also found that different early mathematics skills were predictive of performance in different mathematics domains in third-grade. For example, they found that the number sequence task, which measured counting ability and mental number lines, given in first grade, explained significant variation in the third-grade scores in three of the four domains examined, although when the variables of reading ability and free and reduced lunch were added into the equation the relationship was no longer significant (Kiss et al., 2019). They also found that the third-grade domain of Numbers and Operations was best explained by first grade skills of composing and decomposing numerals, number sequence, and verbal subtraction (Kiss et al., 2019).

The studies described thus far have considered early mathematics abilities as predictors of later achievement as far as middle school; Watts et al. (2014) were interested in whether early mathematics abilities were predictive of high school achievement. They were also interested in whether early grade growth in math achievement would be predictive of later achievement (Watts et al., 2014). The authors utilized the data from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development. The participants came from 10 different rural and urban areas across the United States and were recruited at birth (Watts et al., 2014). The Woodcock Johnson - Revised Applied Problems Subtest (Woodcock et al., 2001) was given at 54 months, first grade, third-grade, fifth grade, and age 15. To measure early reading and cognitive ability the participants were given the Woodcock Johnson Reading and Cognitive Ability Subtests (Woodcock et al., 2001) at 54 months and in first grade (Watts et al., 2014). The authors also considered changes in attention using an assessment in which children are asked to press a button when a target image appears and then they are shown a series of images. Attention is measured by the proportion of correct responses to the target image and impulsivity by the proportion of incorrect responses to the incorrect image (Watts et al., 2014). This assessment was administered at 54 months and first grade. Finally, they considered the possible covariates family background and individual characteristics (Watts et al., 2014). They found that even after adjusting for differences in other academic skills, attention, and personal and family background characteristics, preschool and first grade mathematics abilities were highly significant predictors of mathematics achievement through the age of 15 (Watts et al., 2014). Interestingly, they also found that early elementary school growth in mathematics was also a very significant predictor of high school math achievement. Specifically, they found that an increase of one standard deviation in mathematical ability at 54 months was associated with an increase of a quarter of a standard deviation in mathematical ability at the age of 15 (Watts et al., 2014). They found that growth between 54 months and first grade was just as predictive of math achievement at 15 as it was predictive of math achievement in third-grade (Watts et al., 2014). The authors noted that they had further advanced the research in that while other studies have found the importance of counting and simple addition and subtraction as predictors of later elementary school math achievement they were able to demonstrate that it is also predictive of high school math achievement (Watts et al., 2014).

Going even beyond high school achievement Ritchie and Bates (2013) considered the link between mathematical and reading skills in childhood and midlife socioeconomic status. Data for the study were drawn from the National Child Development Study. This study enrolled infants born in England, Scotland and Wales in the first week of 1958 as well as 920 immigrants born during the same time. The total sample size was 17,638 (Ritchie & Bates, 2013). This particular study used information from when the participants were 7, 11, 16, and 42 years of age. Interestingly, the participants were given different measures at each interval. At seven years of age the Problem Arithmetic Test

(Kellmer Pringle et al., 1966) and the Southgate Group Reading Test (Southgate, 1958) were administered, at 11 their intelligence was measured, at 16 their academic motivation was measured, and at 42 they reported their educational duration and the authors determined their attained SES using their occupation, housing, and gross income at their current job (Ritchie & Bates, 2013). They found that mathematics and reading at the age of seven was substantially and positively related to socioeconomic status at the age of 42. This relationship was found to be independent of confounding variables (Ritchie & Bates, 2013).

A study that also looked at early childhood predictors of later mathematics performance but from a very different angle was conducted by Wolfgang, Stannard, and Jones in 2001. They considered whether high levels of performance in LEGO play would be correlated with later mathematics achievement. Using a scale based on the Piagetian theoretical framework they rated 37 three-and four- year-olds on their “adaptiveness” and “integration” in the use of LEGOS. They then looked at both the students' grades as given to them by their teachers and their standardized test scores in mathematics (Wolfgang et al., 2001). They found that while LEGO performance was not significant for either mathematics grades or test scores at the third or fifth grade level, it was significantly related to standardized test scores at the seventh-grade level. More interestingly, all outcome variables at the middle and high school level were statistically significant (Wolfgang et al., 2001).

It is clear there is a strong predictive relationship between early mathematics understanding a later achievement. To better understand this relationship a Finnish study by authors considered three hypotheses (Aunola et al., 2004). Two of the three are relevant here. These hypotheses were related to the question of how early mathematics understanding develops and the trajectory of this development. The sample consisted of 194 5- to 6-year-old children living in Finland (Aunola et al., 2004). The children were participants in the Jyva¨skyla Entrance IntoPrimary School Study. The participants were tested twice in their year of preschool, twice during their first year of schooling, and twice during their second year of schooling (Aunola et al., 2004). The authors found that the individual differences between mathematical abilities of students grew larger as students progressed from preschool into elementary school. The rate of growth was faster for students who entered preschool with stronger math abilities and the rate of growth was slower for students who entered preschool with weaker mathematics understanding (Aunola et al., 2004).

Clearly, mathematical understanding at an early age is an important precursor to later achievement, it is therefore important to understand whether specific mathematical concepts are more important for later achievement. Research has identified a few areas that seem to be of particular importance. Counting and Numeracy (Aunio & Niemivirta, 2010; Aunola et al., 2004; Nelson & McMaster, 2019; Nguyen et al., 2016), general number sense (Geary et al., 2007; Jordan et al., 2007), and spatial reasoning abilities (Holmes et al., 2008; Lauer & Lourenco, 2016; Lowrie et al., 2016) have all been found to be of particular importance.

Important Math Concepts in Early Childhood Math: Counting and Numeracy

Research has demonstrated that counting abilities are one of the important predictors of later success in mathematics (Aunio & Niemivirta, 2010; Aunola et al., 2004; Nelson & McMaster, 2019; Nguyen et al., 2016).

Nguyen et al. (2016) looked at whether different kinds of mathematical knowledge would predict later math achievement for students of low-income and minority backgrounds. The authors considered data from a study that was considering the effectiveness of an early mathematics curriculum Building Blocks. The study utilized data points from preschool and fifth grade for 781 students (Nguyen et al., 2016). Preschool aged students were given the Research-based Early Mathematics Assessment (Clements et al., 2008) in both the fall and the spring to measure their mathematics competencies. The students were tested again in the fifth grade using the fifth grade Tools for Elementary Assessment in Math 3–5, a variant of the Research-based Early Mathematics Assessment (Clements et al., 2008). The authors found that while geometry, patterning, and measurement skills were predictive of later mathematics achievement, counting and numeracy skills were most predictive of later mathematics achievement (Nguyen et al., 2016). In this study counting was conceptualized to include verbal, or rote counting, number recognition, maintaining one-to-one correspondence, counting with cardinality, and counting forward and backward from a given number (Nguyen et al., 2016). This finding is strengthened by a meta-analysis published by Nelson and McMaster (2019). The authors considered studies regarding the effects of math interventions targeted at young children. One of their findings was that among intervention characteristics that they coded for counting with one-to-one correspondence and ordinal numbers was the only numeracy skill that significantly predicted treatment effects (Nelson & McMaster, 2019).

The study described earlier by Aunola et al. (2004) also considered, in addition to the hypothesis already described the most important precursors to later math achievement. The authors found that counting ability was a strong predictor of later mathematics achievement. This study specifically considered counting ability, visual attention, which they described as the ability to maintain selective visual attention, listening comprehension, and metacognitive knowledge. When considering the hypothesis related to antecedents of future math achievement the study found that counting ability at the beginning of preschool predicted both the student's later math performance level and their growth rate, or the rate at which their mathematical abilities improved (Aunola et al., 2004).

A study of Finnish kindergarten students also found that relational and counting skills are predictive of later overall mathematics achievement (Aunio & Niemivirta, 2010). This particular study considered the data of 212 Finnish kindergarten children who had taken the Finnish Early Numeracy Test (Van Luit et al., 2006). The children were tested again in 1st grade using items from the Mathematics School Test (Ikäheimo et al., 2002). First grade grades as given by the classroom teacher were also utilized (Aunio & Niemivirta, 2010). In addition to the finding that relational and counting skills were predictive of 1st grade skills and overall performance they also found that parental education had a significant effect on the applied arithmetic skills (Aunio & Niemivirta, 2010).

Important Math Concepts in Early Childhood Math: General Number Sense

Another way to develop understanding of which mathematical concepts are most beneficial for students, is to consider the differences between typically achieving students in mathematics and low achieving students in mathematics. One such study differentiates between typically achieving students, low achieving students, and students with mathematical learning difficulties (Geary et al., 2007). Among other hypotheses, the authors hypothesized that students with mathematical learning difficulties would have deficits across a range of math domains, while students who were low achieving in mathematics would have deficits for only a subset of the domains (Geary et al., 2007). All kindergarten students from 12 elementary schools were invited to participate resulting in 15 students in the mathematical learning difficulties group, 44 students in the low achieving group, and 46 children in the typically achieving group. The students were assessed in the spring of their kindergarten year and in the fall and the spring of their first-grade year (Geary et al., 2007). The spring tests consisted of achievement and intelligence measures and the fall assessments consisted of speed of processing tests and mathematical tasks. The speed of processing assessments consisted of the children identifying the quantity of between 0 and 9 small objects. The mathematical task included a number estimation task in which students utilized number lines and counting tasks in which a puppet counted chips and the students were asked about the accuracy of the count (Geary et al., 2007). The important result for the purposes of this paper was that the low achieving group was the most differentiated from the typically achieving group in their fluency of processing numbers, making number line estimates, and retrieving addition facts (Geary et al., 2007).

A longitudinal study considered the predictive nature of number sense in kindergarten (Jordan et al., 2007). The authors use the terms number sense and number competence interchangeably. This study was the final portion of The Children’s Math Project and investigated whether children’s kindergarten number competence was predictive or first grade performance, rate of growth in math achievement between first and third-grade, and whether the rate of growth in number competence would predict later mathematics achievement and growth (Jordan et al., 2007). The participants, 277 children from six schools in the same district in Delaware, were selected because the district served both low and middle-income families. The students were assessed 11 times between kindergarten and third-grade. They were given a number competency core battery which was a series of questions and activities developed by the authors for the purposes of this study. This was administered four times in kindergarten and twice in first grade and included items that addressed counting, number knowledge, nonverbal calculation, story problems, and number combinations (Jordan et al., 2007). They were given the Calculation and Applied Problems portions of the Woodcock–Johnson II (McGrew & Woodcock, 2001) in the spring of first grade, twice in second grade, and twice in third-grade (Jordan et al., 2007). The authors found that high number competence in kindergarten was a strong statistically significant predictor of high achievement on the measure of calculation and applied mathematics in third-grade. The level of number competence in kindergarten was also a predictor of the rate of achievement between first and third-grade although this was a more modest predictor (Jordan et al., 2007). The authors also found that kindergarten performance on number combinations and story problems was a predictor of both achievement and also growth between first and third-grade (Jordan et al., 2007). The authors concluded that children who leave kindergarten with weak number competencies might never catch up to their peers who enter first grade with stronger number competence (Jordan et al., 2007). Jordan et al. (2010a) utilized the same data to further consider the relationship between number sense and later achievement. In the later study they concluded that number sense was as strong of a predictor in third-grade as it was in first grade. They also found that it was most predictive of applied problem solving (Jordan et al., 2010a).

Important Math Concepts in Early Childhood Math: Spatial Reasoning

Research has also suggested that spatial reasoning abilities are predictive of math achievement (Holmes et al., 2008; Lauer & Lourenco, 2016; Lowrie et al., 2016). One study considered the relationship between representations of numerical magnitude and the acquisition of new numerical information (Booth & Siegler, 2008). Specifically, the purpose of this study was to examine whether first grade students' representations of numbers between 0 and 100 on a number line was related to their existing mathematical knowledge or to their ability to acquire new mathematical knowledge. One hundred and five 1st grade students from four different schools in a middle-class school district were randomly assigned to one of four conditions (Booth & Siegler, 2008). One group was the computer-generated group. This group was presented with four unfamiliar addition problems, as they tried to learn the answers to the problems the computer provided them with a number line labeled with 0 and 100 and the magnitude of the addends correctly represented. The child generated group was asked to estimate for themselves the magnitude of the addends and the sums on a number line that was labeled with 0 and 100 as they learned the answers to four addition problems. In the child and computer-generated condition the children estimated the magnitude on the number lines and then the computer showed them the correct magnitudes on the number line as they tried to learn the answers to the problems. Finally, the control group were given the same problems as the other three groups but were never asked to create a visual representation nor were they given one (Booth & Siegler, 2008). The students participated in four sessions. To assess the students' knowledge of numerical magnitudes, a computerized number line estimation task was given. General mathematical knowledge was assessed as well as short term memory for numbers. The students were also given thirteen addition problems with answers between 0 and 100 to examine their knowledge of addition (Booth & Siegler, 2008). The authors found that even after other variables for arithmetic learning were controlled for, linearity of magnitude representations was predictive of arithmetic learning (Booth & Siegler, 2008). They also found that providing the representations of the magnitudes of the addends and the sums increased the children's learning of the addition problems while having children generate their own representations did not augment their learning, in fact it might have weakened it (Booth & Siegler, 2008).

Another study that considered the relationship between spatial reasoning and mathematics understanding looked at the development of spatial reasoning between infancy and preschool age and the ability of spatial reasoning at infancy to predict mathematical abilities at the age of 4 (Lauer & Lourenco, 2016). The participants were recruited from a pool of families which had expressed interest in participating in research previously. There were 53 children who participated as infants and again at the age of three (Lauer & Lourenco, 2016). Between the ages of 6 and 13 months the infants were assessed in their ability to engage in a mental transformation task of a two-dimensional shape. Then, when the children were four, they were assessed in a variety of areas. The researchers administered the Children's Mental Transformation Task (Levine et al., 1999) as well as the Woodcock-Johnson III (Woodcock et al., 2001) as a quantitative measure to ascertain their symbolic math achievement. Finally, non-spatial and non-quantitative tasks were given as controls for the children's general cognitive abilities (Lauer & Lourenco, 2016). The authors found that there was significant stability in children's spatial performance. The infants who performed better at infancy on the spatial reasoning task had greater spatial competence at the age of four even when general cognitive abilities were controlled (Lauer & Lourenco, 2016). Interestingly, the infants scores on the spatial change-detection test did not predict their performance on any of the cognitive measures given at age four although they significantly predict the four-year old's performance on the Woodcock-Johnson III (Woodcock et al., 2001), the symbolic quantitative measure used in this study (Lauer & Lourenco, 2016).

A study conducted in England asked 51 seven- to eight-year-olds and 56 nine- to ten-year-olds to participate in two testing sessions. The first testing session consisted of two visuospatial sketchpad tasks and the second session consisted of an age-appropriate mathematics assessment addressing the four areas of the mathematics curriculum: number and algebra, shape, space and measures, handling data, and mental arithmetic (Holmes et al., 2008). The results demonstrated significant correlations between the students' visuospatial sketchpad task scores and their performance on the mathematics assessment. One curious finding was that in the 9- and 10-year-old group, the performance on the visuospatial sketchpad task predicted significant variance in both number and algebra and in handling data (Holmes et al., 2008).

A study conducted in Australia also examined the relationship between spatial reasoning and mathematics performance (Lowrie et al., 2016). The participants included 181 year 5 and year 6 students who were assessed in two different sessions. In one session they were given the Spatial Reasoning Instrument, this instrument consists of three constructs: spatial visualization, mental rotation, and spatial orientation (Lowrie et al., 2016). The other session consisted of a mathematics performance assessment. The authors used items from the national test used in Australia which covered number, geometry, and measurement, in equal proportions (Lowrie et al., 2016). The authors found that all the mathematics topics were statistically significantly correlated to the spatial reasoning constructs. Not surprisingly, the correlation between the geometric mathematics questions and the spatial constructs was higher than the correlation between the spatial constructs and the non-geometric topics (Lowrie et al., 2016). It is also interesting to note that the authors found that while the three spatial constructs were statistically significantly related, there was sufficient unexplained variance that it seems that the three different constructs are all individually important (Lowrie et al., 2016).

Conclusion: Early Childhood Number Understanding and Math Achievement

There is a predictive relationship between early childhood mathematical ability and later achievement (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). This has been shown to be the case not only in terms of kindergarten mathematics ability predicting third-grade mathematics achievement (Kiss et al., 2019), but in terms of preschool and first grade mathematics abilities predicting mathematics achievement at the age of 15 (Watts et al., 2014). It is also clear that there are specific abilities that are especially important for developing mathematical understanding later in life. Counting and numeracy seem to be important (Aunio & Niemivirta, 2010; Aunola et al., 2004; Nelson & McMaster, 2019; Nguyen et al., 2016), as well as general number sense (Jordan et al., 2007), and spatial reasoning (Holmes et al., 2008; Lauer & Lourenco, 2016; Lowrie et al., 2016).

Early mathematical understanding is vital to later success (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). This understanding directs us to question whether certain populations of students are more likely to enter school with less of these vital mathematical understandings than other students. Knowledge of who is likely to face the issues described can better prepare schools and communities to address the problem. Much research has considered whether students from lower socioeconomic backgrounds enter school at an academic disadvantage.

Socio Economic Status and Achievement

Socioeconomic status has far reaching effects on academic performance (Bradley & Corwyn, 2002; Noble et al., 2005; Nores & Barnett, 2014; Sirin, 2005). A meta-analysis examining this relationship was done by Sirin (2005). Only including quantitative research between 1990 and 2000, that utilized any measure of SES and academic achievement, he identified 58 studies to be included in his meta-analysis. The study found a strong correlation between socioeconomic status and educational performance (Sirin, 2005). A more distressing finding was that the grade level of the student was found to be a significant moderator, with the increase in grade associated with a larger effect size until high school (Sirin, 2005).

Further supporting the relationship between socioeconomic status and academic achievement is a policy report for the National Institute for Early Education and Center on Enhancing Early Learning conducted by Nores and Barnett (2014). The policy report mainly drew from three sources of data: the State of the Preschool series iii, the Early Childhood Longitudinal Study- Kindergarten Cohort 2010/11 iv, and the Early Childhood Longitudinal Study-Birth Cohort 2001. The report aimed to consider "readiness gaps" at kindergarten entry, the extent of "opportunity gaps" in early care and education services, care arrangements at the age of 2, and early care and education arrangements for children aged 3 and 4. Finally, they considered state pre-kindergarten policies and their impacts on enrollment, quality standards, and funding for children aged 3 and 4 (Nores & Barnett, 2014). In their consideration of readiness gaps at kindergarten they found a continuous increase in scores across the range of family income. This gap was large, with students from the bottom income quartile about 0.4 *SD*s below the mean and children from the top income quartile about 0.4 *SDs* above the mean in both reading and mathematics readiness (Nores & Barnett, 2014). The authors also found that educational achievement of the parents had impacts on the kindergarten readiness of the students. Children of parents who had dropped out of high school entered kindergarten 0.60-0.65 *SDs* below the mean and almost 1 *SD* below children of college-educated parents (Nores & Barnett, 2014). Utilizing data from the Early Childhood Longitudinal Birth Cohort (ECLS-B) study which involved a national sample of two-year-olds in 2001 the authors also considered care that children were likely to experience in their years before Kindergarten. In terms of pre-school care, higher income families were more likely to have their children enrolled in "center care" while low-income families were more likely to have their children in home care. Most of the home care was deemed low quality (Nores & Barnett, 2014).

Yet another example of the gaps between high and low socioeconomic status was found in a study examining the impact of socioeconomic status on the developing brain by Noble et al., (2005). The authors specifically investigated neurocognitive systems. The participants were 60 kindergarten students, half of whom were from low socioeconomic backgrounds and half of whom were from middle socioeconomic backgrounds, all were African American English-speaking students (Noble et al., 2005). Differences in socioeconomic status were associated with a large effect size for the differences in the performance for language systems and a moderately large effect size for the executive system (Noble et al., 2005). Interestingly, they also found that while both socioeconomic status and executive function ability predicted language ability, they also found that socioeconomic status did not account for variance in executive function ability beyond what is predicted by language performance (Noble et al., 2005).

Clearly, this is a complicated relationship. In a review of research related to the relationship between socioeconomic status and child development, Bradley and Corwyn (2002) describe a wide variety of both mediating and moderating variables. In their review they describe access to resources, differences in cognitively stimulating materials and experiences, parental expectations and styles, teacher attitudes and expectations, stress reactions, and health behaviors or lifestyle all as variables that mediate the relationship between socioeconomic status and child development (Bradley & Corwyn, 2002). The authors also described research that demonstrates that the socioeconomic level of the neighborhood in which a child grows up can have considerable impact. For example, the authors cite a variety of research demonstrating the effect of neighborhood on health, behavior, and achievement even when the individuals' level of education and income are controlled for (Bradley & Corwyn, 2002).

Research specifically looking at the association between neighborhood and later achievement was conducted with the purpose of linking data from two population-based databases in British Columbia. The two population-based databases were the Early Development Instrument which was given to all kindergartens in British Columbia and the Foundation Skills Assessment given to fourth grade students in British Columbia (Lloyd & Hertzman, 2009). The authors also used an indicator of socioeconomic character of the neighborhoods to make connections between the trajectories of the students and the neighborhoods in which they lived. They created a Community Index of

Child Development that was an index of the linked data that was used to describe the linked data at a neighborhood level (Lloyd & Hertzman, 2009). The study reported an association between the trajectories of the children based on the neighborhoods in which they lived and a wide variation in children's trajectories between kindergarten and fourth grade depending on their kindergarten district of residence (Lloyd & Hertzman, 2009). Importantly, they also found that in some high vulnerability neighborhoods the students fall further behind other students but in some high vulnerability neighborhoods the students tended to catch up to students in low vulnerability neighborhoods (Lloyd & Hertzman, 2009).

Level of parental education is often used as a proxy variable for socioeconomic status. As the level of education increases often the socioeconomic status increases as well (Aunio & Niemivirta, 2010). A study considering the impact of parent education on student achievement found that the relationship between parental education and student achievement was indirectly related through parental educational expectations and parental behavior but that this link differed between European American families and African American families (Davis-Kean, 2005). This study used the nationally representative data set, the 1997 Child Development Supplement of the Panel Study of Income Dynamics. The sample for this study included 868 8–12-year-olds (Davis-Kean, 2005). A wide variety of measures were used in this study. The students took four subscales of the Woodcock-Johnson-Revised Tests of Achievement (Woodcock & Johnson, 1989/1990), the caregivers completed a survey and were interviewed, observations of the home environment were collected, and the primary caregiver's literacy was assessed using the Woodcock-Johnson Passage Comprehension Test

(Woodcock & Johnson, 1989/1990). The variables measured included parental expectation for achievement, measured with an ordinal variable, three aspects of the home environment: reading, parent–child play behavior, and parental warmth which was measured using the survey and the home observation, family socio economic status and structure which was measured using three indicators and the highest education in the household was used as the indicator of family education (Davis-Kean, 2005). The study looked at two samples, African American families and European American families. They found that in the African American sample the relationship between educational attainment and family income were indirectly related to student achievement through their educational expectations, reading, and warmth of parent child interactions (Davis-Kean, 2005). In the European American sample parental education attainment had both a direct and indirect relationship with student achievement and the total effect of parental educational attainment was much greater than the effect of family income (Davis-Kean, 2005). One of the authors' conclusions was that low socioeconomic status does not necessarily inhibit student achievement, the parental educational expectations were both directly and indirectly related to student achievement of European American students and they exerted a strong indirect influence on the African American sample (Davis-Kean, 2005).

Another study that more specifically looked at achievement gaps between races was done by Burchinal et al. (2011). The authors of this study examined the trajectories of low-income African American students and low-income white students. Their sample consisted of 1,364 families who participated in the Study of Early Child Care and Youth Development. The families were recruited in 1991 from hospitals located in 10 sites around the United States. The children were assessed at 6, 15, 24, 36, and 54 months old and in first, third and fifth grade (Burchinal et al., 2011). The authors utilized individual standardized tests, observations of families and school settings, and parent and teacher reports of behavior. The authors found that a substantial race gap was present at 3 years old (Burchinal et al., 2011). They also found that differences in family and school factors can account for a significant portion of the differences in the trajectories (Burchinal et al., 2011).

More positive news comes from a study investigating the trends in school readiness. Specifically, the authors considered whether socioeconomic and racial readiness gaps have widened or narrowed between 1998 and 2010 (Reardon & Portilla, 2015). The authors used data from two Early Childhood Longitudinal Studies- Kindergarten Cohort and the Early Childhood Longitudinal Study- Birth Cohort. The Early Childhood Longitudinal Studies - Kindergarten Cohort included students who entered kindergarten in the fall of 1998 and 2010 and the Early Childhood Longitudinal Study- Birth Cohort included children who entered kindergarten in fall 2006 or 2007 (Reardon & Portilla, 2015). They found that socioeconomic readiness gaps, and to a lesser extent racial readiness gaps had narrowed in the 12 years between studies. The narrowing of the readiness gap for socioeconomic status and between white and Hispanic students was moderately large and statistically significant while the decrease in the gap between African American students and white students was smaller. This gap was only statistically significant in measures of reading but not in measures of mathematics achievement (Reardon & Portilla, 2015).

There are clearly many factors that influence a child's readiness for kindergarten and eventual academic achievement. While many studies link socioeconomic status and kindergarten readiness it is difficult to demonstrate causation (Duncan & Magnuson, 2005). A 2005 study questioned whether socioeconomic status could account for racial and ethnic gaps for American preschoolers and attempted to untangle the many factors related to socioeconomic status. The study utilized data from the 1998 Early Child-hood Longitudinal Study (Duncan & Magnuson, 2005). They considered a wide range of factors. To measure family economic and social resources they looked at four items; whether the caregiver was a high school dropout, whether the child came from a single-parent family, whether the mother was employed or if she had a job with low prestige, and finally if the family lived in an unsafe neighborhood (Duncan & Magnuson, 2005). They also considered seven resource related factors that are commonly faced by poor families: large family size, residential instability, harsh discipline, few learning materials, low birth weight, young parents, and high levels of maternal depressive symptoms. Finally, they considered four dimensions of parental socioeconomic resources: income, education, family structure, and neighborhood conditions (Duncan & Magnuson, 2005). They found children living in poverty are twice as likely to have a given hardship and for some of the hardships that number is three times more likely (Duncan & Magnuson, 2005). This informs us as to the complexity of the relationship between a student's background and their eventual achievement in the classroom.

Mathematics and Socioeconomic Status

Early mathematical understanding is an important precursor to later achievement (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014) and there is a strong relationship between socioeconomic status and kindergarten readiness

(Bradley & Corwyn, 2002; Noble et al., 2005; Nores & Barnett, 2014; Sirin, 2005). For the purposes of this paper, it is important to consider the interaction of these two ideas. There is a strong link between socioeconomic status and kindergarten readiness in mathematics (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). Especially informative on this topic is a policy information report completed by Coley in 2002. Examining 95% of the 20,000 children in the ECLS-K who entered kindergarten for the first time in the Fall of 1998, he found socioeconomic status was related to proficiency across all mathematics tasks. The children in higher socioeconomic status groups were more likely to be proficient than were children in lower socioeconomic status groups. In comparing the highest socioeconomic status quintile to the lowest socioeconomic status quintile there was a difference of about one standard deviation in recognizing numbers and shapes, a difference of more than one standard deviation in understanding relative size, a difference of about one standard deviation in understanding ordinal sequence, and finally, a difference of about a half of a standard deviation in understanding of addition and subtraction (Coley, 2002). The more recent policy report completed by Nores and Barnett (2014) looked at the 2010/2011 kindergarten cohort from the Early Childhood Longitudinal Study. They found that in both math and reading readiness, children in the bottom income quartile scored about .4 of a standard deviation below the mean, while children in the top income quartile are about .4 standard deviations above the mean. This represents a gap of almost a full standard deviation between the bottom and top income quartiles (Nores & Barnett, 2014). While the two studies did not break the test down in the same way it appears that the gap present in 1998 was still present in 2014.

While the study from Finland by Aunola et al. (2004) was not intended to look at mathematics achievement and socioeconomic status they did report that they found that children whose parents were employed in blue-collar professions performed more poorly in math and demonstrated lower levels in initial counting skills than did the students whose parents were employed in white-collar professions (Aunola et al., 2004).

A study conducted by Jordan et al. (2007) considered the development of number sense through kindergarten and how socioeconomic status affected that development. Specifically, they examined the growth curves through the kindergarten year on a number of number sense competencies. The final sample for the study consisted of 411 kindergarteners from six different schools in the same district (Jordan et al., 2007). The caregivers completed surveys at the beginning of the year regarding the amount of and type of numeracy and reading activities that they engaged in at home. Because all of the schools were in the same district, they were all using the same math curriculum and all of the kindergarten classrooms were observed twice to ensure that they were exposing the students to a similar quantity of time engaged in math activities and that the activities were being presented in a similar manner (Jordan et al., 2007). The students were given a number sense battery four times over the course of the school year with the interval between the tests approximately two months apart. The battery considered counting skills, number recognition, number knowledge, nonverbal calculation, story problems, number combinations, estimation, and number patterns (Jordan et al., 2007). The students were also given a reading test on the final testing date. The researchers found that while controlling for other background variables the low-income students performed worse on most of the number sense tasks relative to their middle-class peers (Jordan et al., 2007).

They also found that while low-income students and middle-income students progressed similarly on many tasks there was a marked difference in their growth on the story problem tasks (Jordan et al., 2007). Low-income students showed almost no growth on the story problem tasks even when reading proficiency was controlled (Jordan et al., 2007). The researchers generally found that in terms of growth curve there were generally three groups: students who ended with a low level and had a fairly flat rate of growth, students who ended with a high level and maintained moderate to steep growth, and a group who ended with an average level with moderate growth. Many of the students were in the low-level flat growth group for story problems but they found that low-income students were four times more likely to be in this group than the middle-income students (Jordan et al., 2007). The same was true for the number combination tasks. But, when students were given the same calculations in a nonverbal context with visual referents middle and low-income students made comparable progress (Jordan et al., 2007). The authors found statistically significant results when they looked at gender and reading proficiency. They found that boys scored significantly higher on overall number sense. They also found that reading proficiency predicted performance on all number sense measures although it did not predict rate of growth (Jordan et al., 2007).

Using a correlational research model Kalaycioglu (2015) examined patterns between socioeconomic status, math self-efficacy, math anxiety, and mathematics achievement. The author utilized data from 8,806 students who took the PISA as 15-year-olds in 2012. The students were from England, Greece, Hong Kong, the Netherlands, Turkey, and the United States (Kalaycioglu, 2015). The relationship between socioeconomic status and performance on the PISA was statistically significant in every country (Kalaycioglu, 2015).

In the study conducted by Jordan et al. (2009) that considered the predictive relationship between early math understanding and later achievement that was described earlier, the authors also found the relationship between low-income and poor performance in mathematics in third-grade was mediated by weak number competence in kindergarten. This indicates that if we can intervene with low socioeconomic students to boost mathematics understanding we can alleviate the achievement gap between low and high socioeconomic students in mathematics. Unfortunately, this is not a simple relationship that is easily dissected and understood.

Moderating Variables of Math Achievement and Socioeconomic Status

There are a wide variety of moderating variables that affect the relationship between socioeconomic status and mathematics achievement (Reyes et al., 1988). For example, students with more educated parents do better on both achievement and cognitive tests than children of parents with less education (Duncan & Magnuson, 2005). In looking at the relationship between parent education and kindergarten readiness Nores and Barnett (2014) found children whose parents dropped out of high school enter kindergarten .60-.65 *SDs* below the mean and almost 1 *SD* below children of college-educated parents. Children of parents with a high school degree also underperform, entering kindergarten almost .30 *SDs* below the mean and with a gap of about .70 *SDs* when compared to children with college-educated parents (Nores & Barnett, 2014). There is also a body of research that demonstrates that the neighborhood of the child has far reaching effects on academic achievement (Bradley & Corwyn, 2002). When considering school location as a moderator Sirin (2005) found that the relationship between socioeconomic status and academic achievement was stronger for students who attended schools in suburban settings than for students who attended schools in rural or urban settings. In looking at the relationship between race and ethnicity and the home and classroom environment and mathematics achievement Sonnenschein and Galindo (2015) found that White children attended classes with more children demonstrating proficient mathematics skills than Black or Latino children. Sirin (2005) analyzed minority status as a possible moderator. He found the correlation between socioeconomic status and educational outcomes decreased as the number of minority students in the sample increased. Another important moderator is native language. Nores and Barnett (2014) found that non-English speakers perform about half a standard deviation below English-speaking children in reading and math upon entry into kindergarten. Duncan and Magnuson (2005) attempted to untangle the complexities of socioeconomic status, achievement, and the wide variety of moderators in a paper aimed at answering the question of whether socioeconomics can account for racial and ethnic gaps for American preschoolers. They considered four items that are common indicators of inadequate family economic and social resources and seven items that are resource related disadvantages that are often faced by poor families. They found more than twice as many poor as non-poor children suffer a given item, and for several items the rate is more than three times as high for poor than non-poor children (Duncan & Magnuson, 2005). Basically, a child in poverty likely faces many hardships that affect their academic achievement when compared to a non-poor child.

One of the research questions in a study conducted by Galindo and Sonnenschein (2015) asked to what extent children's mathematics proficiency at the beginning of kindergarten mediated the relationship between socioeconomic status and children's mathematics proficiency at the end of kindergarten. The authors utilized data from the Early Childhood Longitudinal Study Kindergarten class 1998-1999. With a final sample of 19,280 students the authors analyzed the data from the ECLS-K math assessment (Galindo & Sonnenschein, 2015). The spring kindergarten scores were the dependent variable. The authors found a significant relationship between socioeconomic status and end of kindergarten mathematics proficiency scores (Galindo & Sonnenschein, 2015). In terms of their research question, they did find that mathematics proficiency upon entry to kindergarten did mediate this relationship. In fact, they found mathematics proficiency upon entry to kindergarten decreased the achievement gap by a third (Galindo & Sonnenschein, 2015). The authors argue that this is because students who enter kindergarten proficient in math are ready to profit from classroom instruction (Galindo & Sonnenschein, 2015).

In another study by the same authors utilizing the same data set they considered the impact of both home and classroom learning environments on student mathematics achievement (Sonnenschein & Galindo, 2015). The authors were specifically interested in comparing the performance of Black and Latino children, to that of White children. Because, for this study, they only used the data for Black, Latino, and White children they ended up with a sample size of 12,610 children (Sonnenschein, & Galindo, 2015). The authors found that upon entry to kindergarten the White children scored higher in mathematics proficiency. This gap decreased by the end of kindergarten (Sonnenschein & Galindo, 2015).

With the goal of clarifying what specific math knowledge is most predictive of later math achievement Rittle-Johnson et al. (2017) conducted a longitudinal study with over 500 low-income children from the ages of 4 to 11. The sample consisted of 517 children who had participated in a prior 3-year longitudinal study that began when they were in preschool (Rittle-Johnson et al., 2017). The students were originally from 57 preschool classes at 20 public schools and from 4 Head Start sites in a large urban city in Tennessee. There were 771 students in the original study, but they were only able to locate and re consent 519. At the time of the follow up study most of the students were in the fifth grade, although 14% had been retained a grade and were in fourth grade (Rittle-Johnson et al., 2017). The students were given four different mathematics tests individually, the quantitative concepts subtest from the Woodcock Johnson Achievement Battery III (Woodcock et al., 2001), and the numeration subtest, the algebra subtest, and the geometry subtest of the Key Math 3 Diagnostic Assessment (Connolly, 2007). Teachers also rated the students self-regulation behaviors (Rittle-Johnson et al., 2017). The researchers found that students' abilities in preschool in the areas of nonsymbolic quantity, counting, and patterning knowledge were predictors of fifth grade math achievement. They also found that symbolic mapping, calculation, and patterning knowledge at the end of first grade were predictive of later math achievement (Rittle-Johnson et al., 2017). Importantly, they found that first grade knowledge mediated the relationship between preschool mathematics knowledge and fifth grade achievement (Rittle-Johnson et al., 2017). This is an important finding for the purposes of the present study because it tells us that when we are able to intervene successfully between preschool and first-grade we can make meaningful change in children's long term mathematics achievement.

We know that early mathematical understanding is vital to later success in mathematics (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). Students living in families of low socioeconomic status are more likely to be deficit in these understandings (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). But, understanding that living in a low socioeconomic status family is associated with lower mathematics achievement does not tell us what it is about this environment that leads to deficient mathematical understanding. To better understand this question, we must examine the research related to the home learning environment and mathematics understanding.

Home Learning Environments

If students are entering kindergarten with large differences in their mathematical readiness it is logical to consider that the home learning environment must play an important role. It is vital to understand the differences between various environments and the factors that seem to have the greatest impact on mathematical understanding. This informs our knowledge of how we might intervene and what types of interventions might be most effective.

Indirect Versus Direct Interventions

Before we continue into the specific studies that have home learning environments and later the interventions that occur in the home environment it is important to specify some vocabulary that is used in the research and how that vocabulary will be operationalized here. In the research considering mathematics interventions the terms indirect and direct and informal and formal are often used to describe different means of addressing mathematics ideas. For the purposes of this paper the definition of direct versus indirect described by LeFevre et al. (2009) and LeFevre et al. (2010) is utilized. In this definition direct activities refer to activities in which the goal of the activity is to build numerical processing. Indirect activities are activities in which the focus of the activity is not mathematically based although numeracy related processing might have occurred. Some examples of indirect activities described by LeFevre et al. (2010) include games, cooking, and making or sorting collections. While some of the research cited and described here uses the terms formal and informal to describe similar ideas, all studies will be evaluated using the definition given by LeFevre et al. (2009) and LeFevre et al. (2010).

Home numeracy activities that improve math achievement before kindergarten are useful in tackling the problems associated with the relationship between low socioeconomic status and kindergarten readiness (Galindo & Sonnenschein, 2015; Levine et al., 2010).

In a longitudinal study of 44 pairs of children and their caregivers, Levine et al. (2010) examined the relationship between parents and children's engagement in "number talk" and children's later number knowledge. They found that performance on a number naming activity was positively correlated with the amount of "number talk" previously observed (Levine et al., 2010). But, they also found that when they controlled for socioeconomic status the relationship was still significant (Levine et al., 2010). This was a longitudinal study that involved 44 pairs of children and a caregiver. Each pair was visited in their homes every 4 months beginning when the children were 14 months old until the children were 30 months old. At each visit the pair was videotaped for 90 min. The transcripts were reviewed for the total number of words and number talked was coded into context (Levine et al., 2010). The researchers then tested the children's ability to point to a named number at the age of 46 months. It is important to note that the relationship between the amount of "number talk" and the children's performance on the number naming task was still significant when socioeconomic status was controlled for because it tells us that interventions can be effective in closing the socioeconomic achievement gap.

A 2018 study that attempted to clarify the relationships between the specific home numeracy activities and the specific types of basic number processing abilities found that while number practice at home was significantly related to later number enumeration it was not related to any other variable they considered. They also found that both formal and informal home numeracy applications practice was significantly related to symbolic number line estimation but no other variable (Yildiz et al., 2018). All participants in this study were from either middle or high-income families (Yildiz et al., 2018). This tells us that early numeracy activities can be helpful in preparing children for kindergarten.

In a study regarding how the home environment plays an important role in young children's mathematical understanding the focus was parents' discussion of numbers during informal play. The authors aim was to investigate whether parents number talk during informal play was a predictor of children's early math abilities and whether parents number talk was influenced by parents' beliefs about their own mathematical skills, parents' beliefs about their children's math skills, or parents' number competence (Elliott et al., 2017). The participants consisted of 54 children between the ages of 5 and

6. The children and their parents attended a single one-hour session in which they played freely for 10 min, children completed a mathematics test, and parents completed a number comparison task and questionnaires regarding their views towards mathematics (Elliott et al., 2017). The free play session was video recorded and then coded. The authors found that number talk was not significantly related to the mathematics abilities of the children (Elliott et al., 2017). They also found that parent mathematics ability and the parent's rating of their math abilities were related to the parent's number talk.

A study which considered math talk between children and their caregivers was conducted with families from a Head Start program. The authors considered whether number related experiences at home acted as sources of variation in number skills (Ramani et al., 2015). In this study one caregiver-child experience was observed. In this experience the pairs were given a standard set of toys that were intended to elicit math talk although the caregivers were not aware that math talk was the focus of the study. The authors measured talk regarding foundational number concepts and talk about more advanced numerical concepts. The second aim of the study was to consider the variability in the home environment and how the different experiences impacted the children's numerical knowledge (Ramani et al., 2015). The participants consisted of 33 pairs of caregivers and their children between the ages of 3 and 5 who were recruited from a Head Start program in the mid-Atlantic. The children were given a variety of numeracy tasks and the caregivers completed a survey (Ramani et al., 2015). The authors found that both the caregivers' talk during the interaction and the reported engagement in math related activities in the home predicted the early mathematical knowledge of the children. More specifically, they found that the frequency of the number related activities in the home was predictive of the children's foundational numerical knowledge and the quality of the interaction in terms of math talk, was predictive of the children's advanced numerical knowledge (Ramani et al., 2015).

With the goal of measuring whether the quantity of home numeracy experiences was related to children's mathematical knowledge a study was completed in two Canadian cities (LeFevre et al., 2009). The parents of 258 children completed a questionnaire regarding the frequency with which their children participated in 40 different activities. Children were given measures that considered their performance on assessments measuring their mathematical knowledge and fluency (LeFevre et al., 2009). The authors reported that the parents' reports of the frequency of home numeracy activities were correlated with the children's mathematics performance (LeFevre et al., 2009). The authors also found that indirect numeracy related activities were related to children's fluency with basic numbers (LeFevre et al., 2009). The authors noted that the indirect activities that involved quantitative skills and fluency in addition were the most consistently related. Interestingly, the authors also reported that game playing predicted unique variability in the addition fluency measure (LeFevre et al., 2009).

Furthering our understanding of the relationship between home activities and mathematics performance in children, a study with 110 preschool children in Italy considered both activities within the family environment and numerical information learned at home (Benavides-Varela et al., 2016). The participants were in kindergarten with a mean age of 5.95 years. This particular study differed from studies described earlier in that not only were the children assessed using a variety of numerical tasks, but they were also assessed in their knowledge of a variety of numerical facts that would have been acquired in the family environment. Examples of these facts include, birthdates, number of siblings, and phone numbers (Benavides-Varela et al., 2016). Parents were surveyed regarding the frequency of number and non-number related activities as well as their predictions as to whether their children would correctly identify the numerical facts from the family environment. The numerical information acquired in the family environment was significantly predictive of the children's ability to solve numerical problems in everyday situations, counting ability, and the ability to identify one to one correspondence between sets (Benavides-Varela et al., 2016). Interestingly, the numerical information acquired at home was not related to all numerical skills. Specifically, number line and magnitude comparison tasks were not predicted by numerical knowledge acquired at home (Benavides-Varela et al., 2016). The authors also found a correlation between the frequency of some of the activities engaged in at home and numerical abilities. Specifically, there was a correlation between frequency of playing sports and the children's performance on the number line task. There was also a correlation between frequency of playing board games, knowledge of number related information, and counting abilities. There was no correlation between board game playing and magnitude comparison or number line estimation (Benavides-Varela et al., 2016).

The authors of another study considering the home math environment set out three goals (Zippert & Rittle-Johnson, 2020). The first was to better understand the home math environment. The second aim was to explore the relationship between parents' math beliefs and the support that they provide. Finally, the third aim was to determine whether parent support in three areas, numeracy, pattern, and space, were correlated with student achievement in those areas (Zippert & Rittle-Johnson, 2020). The participants were 63 children in their pre-school year and their parents. The families were recruited from their preschool programs, one of which was a Head Start program, two were private centers, and three were public preschools. Parents completed a survey regarding the frequency with which they engaged in various numeracy, spatial, and patterning activities at home. Children were assessed on patterning, spatial, and language skills in the fall and again in the spring (Zippert & Rittle-Johnson, 2020). The authors found that numeracy activities were the type of activity most frequently reported. They also found that parents' beliefs about their own abilities did help to explain some of the math support provided (Zippert & Rittle-Johnson, 2020). The authors found that the reports of the home math environment rarely were related to the children's performance on the math assessments. They did find that while numeracy activities related to numeracy knowledge, the support was not correlated with the children's performance on the broad mathematical assessment (Zippert & Rittle-Johnson, 2020). There was not a correlation between the broad home math environment and the children's broad math knowledge, patterning support and patterning skills, or spatial support and spatial skills (Zippert & Rittle-Johnson, 2020).

LeFevre et al. (2010) conducted a study in which they tested a variety of parent factors and their relationship to their children's numeracy outcomes. They specifically considered parent education, parent academic expectations, and parent attitudes towards math. The authors assumed that attitudes, knowledge, and beliefs would be operationalized as practices and influence their children's performance (LeFevre et al., 2010). The study was conducted in Greece and Canada with 100 participants from Greece and 104 from Canada. The parents completed questionnaires regarding the previously mentioned factors and information regarding the frequency of a variety of home practices (LeFevre et al., 2010). The Canadian children administered a large number of numeracy tests as part of a different study and the Greek children completed two numeracy tests. In both the Canadian and Greek samples, the children's performance on numeracy tasks was correlated with the frequency of counting money, learning simple sums, doing math in your head, and memorizing math facts. Given these correlations, the children whose parents reported overall higher direct numeracy instruction had higher numeracy scores, direct math activities accounted for 44% of the variance in numeracy items for Greek children and 34% of the variance for Canadian children (LeFevre et al., 2010). In contrast, indirect math activities accounted for 12% of the variance for Greek children and 15% of the variance for Canadian children (LeFevre et al., 2010).

A study conducted by Skwarchuk et al. (2014) utilized the terms informal and formal numeracy activities but the definition that they provided matches the definition described by LeFevre et al., (2010). This study assessed both formal and informal numeracy activities and their predictive relationship to non-symbolic arithmetic and symbolic number knowledge while controlling for visual spatial working memory (Skwarchuk et al., 2014). After recruiting from child care facilities, preschools, play-groups, early learning home visit programs, and a citywide wellness fair the authors established a group of 121 participants from a medium sized city in central Canada. The parents of the kindergarten children completed a survey regarding their academic expectations, literacy and numeracy attitudes, and formal and informal literacy and numeracy practices. A number game checklist was also created to measure informal home numeracy activities (Skwarchuk et al., 2014). The children were assessed by a variety of measures in literacy and numeracy. Their symbolic and non-symbolic numeracy skills were assessed using the Numeration subtest of KeyMath–Revised (Connolly, 2000) and a non-symbolic arithmetic measure that was adapted for the purposes of this study, respectively (Skwarchuk et al., 2014). The authors found that while informal numeracy practices were correlated with non-symbolic arithmetic but not symbolic number knowledge, the opposite was true of formal numeracy practices (Skwarchuk et al., 2014).

Children who grow up living in low socioeconomic status families are more likely to experience difficulties in academic achievement (Bradley & Corwyn, 2002; Noble et al., 2005; Nores & Barnett, 2014; Sirin, 2005). These children are specifically at higher risk for beginning kindergarten behind their peers in mathematical understanding (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). This can be at least partially understood by considering the differences in learning environments that children are likely to encounter. Home numeracy activities do seem to have a positive impact on children's mathematical abilities (Galindo & Sonnenschein, 2015; Levine et al., 2010).

Socio Economic Status and Early Learning Environments

The numeracy environments that children experience influence their mathematical understandings (LeFevre et al., 2009; Ramani et al., 2015, Galindo & Sonnenschein, 2015; Levine, et al., 2010; Yildiz et al., 2018). We also know that students from low socioeconomic backgrounds are more likely to enter school with lower mathematical understandings (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). So, this leads us to question the relationship between socioeconomic status and early learning environments.

One review of the research done by Magnuson and Waldfogel (2005) considered who had access to various types of child care and the quality of that care. They categorized the various types of early childhood care into three types: parental care, informal care (care given by a relative, nanny, or babysitter), and center care or preschool (Magnuson & Waldfogel, 2005). That found that experimental evidence demonstrates that high quality preschool programs do strengthen cognitive development and academic readiness in kindergarten. But the benefits of these programs seem to fade over time (Magnuson & Waldfogel, 2005). Head Start is much more likely to be attended by lower socioeconomic African American and Hispanic children and does seem to have some cognitive and academic benefits, although it is less clear how large these benefits are or how long they last. There is less research on informal or family care. But, what there is seems to show no effect. The authors postulate that this is because there is both excellent and very poor care, and when averaged, they cancel one another out (Magnuson & Waldfogel, 2005). This research tells us that high quality care can make a difference. But it must be followed by high quality education.

Unfortunately, in a policy report that considered both readiness gaps and opportunity gaps, Nores and Barnett (2014) found that higher income families were more likely to have their children in “center care” that was of high quality. To consider the type of care and education that a sample of 4-year-olds received prior to Kindergarten the authors used data from the Early Childhood Longitudinal Birth Cohort (ECLS-B) which provided a national sample of children who were two-years-old in 2000. They found that 57% of their sample of low-income children were enrolled in a preschool program while 77% of high-income children were enrolled in a preschool program. Furthermore, they found that of the low-income children enrolled in preschool only 18% were enrolled in high quality preschool while 29% of the high-income children were enrolled in high quality preschool (Nores & Barnett, 2014).

In a study that considered the impact of home and classroom learning environments on children's mathematics achievement in kindergarten and compared the performance of Black and Latino children to that of White children, Sonnenschein and Galindo (2015) found that engaging in reading activities at home was statistically associated with mathematics proficiency for all three racial/ethnic groups. While this study does not point to a specific intervention it does inform our understanding of the value of engaging in academic activities with children prior to kindergarten.

Students with low mathematical understandings in kindergarten and first grade are less likely to be successful in math in the future (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). Children from low socioeconomic backgrounds are more likely to enter school with low mathematical understandings (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). To better understand the factors that contribute to this relationship we must examine the home numeracy environment. The research tells us that children experience a wide range of home learning environments and these early environments impact their mathematical understandings (LeFevre et al., 2009; Ramani et al., 2015, Galindo & Sonnenschein, 2015; Levine et al., 2010; Yildiz et al., 2018). Now that we have examined the nature of the problem, it is crucial that we consider whether intervention can be successful, and more specifically, whether there are specific types of interventions that have been shown to be especially effective.

Interventions to Build Mathematical Understanding

Efficacy of Interventions in General

There has been a large amount of research related to interventions that occur once students reach our elementary schools. In the meta-analysis of studies regarding studies of math interventions targeted at young children described earlier, Nelson and McMaster (2019) found that in the studies they considered, early numeracy interventions were able to successfully address math skill deficits. They found this was true for students with disabilities and students with math difficulties. They also found the effect size for students identified as low SES was higher than average.

In another meta-analysis conducted by Mononen et al. (2014), which considered the effectiveness and variation in type of early numeracy interventions found encouraging results as to the efficacy of numeracy interventions. The authors identified 19 studies which met the criteria for inclusion in their study. They only included studies that targeted 4- to 7-year-olds who were at risk for mathematical difficulties and studies which utilized random assignment or quasi experimental design among other requirements (Mononen et al., 2014). Overall, the authors concluded that early numeracy interventions can be effective in addressing the needs of students at risk for math difficulties. They came to this conclusion based on the fact that in the studies they utilized, the children who received the interventions outperformed the children who were in the control groups with effect sizes that varied from small to large (Mononen et al., 2014). The instructional design features that they found to produce improvements in mathematics abilities were explicit instruction, peer-assisted instruction, concrete-representational- abstract approach, computer assisted instruction, and games (Mononen et al., 2014).

Efficacy of Specific Interventions

A variety of studies have considered the efficacy of specific interventions. One such study was done by Clements et al. (2011). They examined the generalizability of the Building Blocks curriculum over a variety of settings. The Building Blocks curriculum was funded by the National Science Foundation and is meant to address numeric/quantitative and geometric/spatial ideas and skills (Clements et al., 2011). Two school districts participated in the study and each school within the district was randomly assigned to one of the treatment conditions, they would either use the Building Blocks curriculum or not. The schools which were not one of the Building Blocks treatment schools used other math curriculums (Clements et al., 2011). Fifteen children were randomly selected from each of the preschool classrooms within the schools to be part of the study. All participating teachers from the Building Blocks treatment schools attended eight days of professional development during the first year of the study and five days during the second year. The Research-based Elementary Math Assessment (Clements et al., 2008) was administered as a pretest and posttest to all eligible pre-K children. A wide variety of surveys, observations, and interviews were conducted to ensure fidelity to the program (Clements et al., 2011).The authors found that students who received the Building Blocks intervention outperformed students in the control group on their total mathematics test. They reported an effect size of .72 (Clements et al., 2011). They found the children in the Building Blocks group showed more improvement than the students in the control group on all subtests. The authors also found that at the school level neither the rate of free and reduced lunch nor limited English proficiency predicted mathematics achievement (Clements et al., 2011).

A study involving one of the same authors considered the efficacy of the Spanish version of the supplementary Building Blocks numeracy activities on mathematics performance (Foster et al., 2018). The authors also considered the added value of vocabulary proficiency to math performance. The participants for the study were recruited from an urban school district in Texas. The district was selected due to its large population of Hispanic students participating in a dual language program. In total 31 kindergarten teachers participated (Foster et al., 2018). The students accessed the materials individually on computers during a block of time normally used for computers. The students worked on the computer program for 90 min per week. This time was provided either in two 45 min blocks or three 30 min blocks. The intervention was 21 weeks although it took place over 30 weeks because of school holidays (Foster et al., 2018). Students were assessed at four different time points. The first time point was a few weeks before the intervention began and numeracy and vocabulary were assessed. The second time point was 10 weeks into the intervention and time three was 20 weeks into the intervention. At these two points only vocabulary was assessed. Finally, the students were assessed a few weeks after the intervention had ended. At this point the numeracy, vocabulary, and applied problem solving were assessed (Foster et al., 2018). To asses applied problems students were given the Applied Problems subtest of the Woodcock - Johnson III Tests of Achievement (Woodcock et al., 2007) and in Spanish using the Problemas Aplicados sub test of the Batería III Woodcock- Muñoz Pruebas de Aprovehamient (Muñoz-Sandoval et al., 2005). The authors found the use of the supplementary materials led to statistically significant improvements in the students'

Spanish mathematics achievement (Foster et al., 2018). The improvements did not generalize to their performance on the English mathematics test (Foster et al., 2018).

A study in Los Angeles considered the efficacy of a tablet-based mathematics curriculum for preschoolers called Math Shelf (Schacter & Jo, 2016). The software aimed to incorporate the instructional materials used in Montessori classrooms, developmental mathematics theory, and mathematics content for preschoolers. A total of 162 students participated from 13 preschool classrooms which served predominantly low-income four-year-olds. Ten of the classrooms were assigned to the intervention group and three were assigned to the control group (Schacter & Jo, 2016). The students in the intervention group played Math Shelf for 10 min two days a week. The control group participated in normal classroom mathematics activities. The intervention lasted for 15 weeks. An assessment was created for the purposes of the study which was administered on the iPad and included 44 items. The items focused on quantity discrimination, numeral identification, numeral sequencing, cardinal principle, comparing quantities, and matching numerals to quantities (Schacter & Jo, 2016). The results were encouraging. The authors found that there was a large, statistically significant effect for the intervention on number knowledge compared to the control group. They also found that the students who benefited from the intervention the most were the students who began with the least number knowledge (Schacter & Jo, 2016).

Another study that considered a specific intervention was conducted by Doabler et al., (2019). This study considered the effectiveness of the ROOTS intervention. These authors were specifically interested in the effectiveness of the program for English language learners who were at risk of having mathematics difficulties (Doabler et al., 2019). The authors were also interested to see if there were student level variables that predicted a differential response to the intervention. The intervention program ROOTS utilizes explicit instruction to build students conceptual and procedural knowledge of whole numbers (Doabler et al., 2019). Twenty-three schools from Oregon and two school districts in Massachusetts participated in this study over the course of two years. Kindergarten students from these schools were randomly assigned to be in either a 2:1 ROOTS intervention group, a 5:1 ROOTS intervention group, or a control group (Doabler et al., 2019). For the purposes of this study the 2:1 group and the 5:1 group were combined into one group for analysis. In the fall of their kindergarten year 3,066 students were screened for early mathematics proficiency. Students were considered eligible for the ROOTS program only if they were deemed, by the screening scores, to be at risk for mathematics difficulties, leaving 1,251 students eligible (Doabler et al., 2019). The scores of these students were rank ordered within each classroom and the 10 eligible students with the lowest scores were randomly assigned to one of the three conditions. In the ROOTS intervention groups, the intervention was delivered in 20 min sessions, 5 days a week, for 10 weeks (Doabler et al., 2019). Five measures of whole number understanding were administered to all students. They were given a measure of early numeracy skills, an oral counting measure, a number sense measure, a measure of mathematical ability, and an achievement test (Doabler et al., 2019). At post-test the students were given a distal measure of mathematics achievement, the Stanford Early School Achievement Test (Harcourt Educational Measurement, 2003). The authors found that the English language students who participated in the ROOTS intervention treatment groups demonstrated statistically significant gains when compared to the control group on both proximal and distal measures (Doabler et al., 2019). They also found the English language learners who demonstrated lower proficiency in English seemed to make greater gains than the English language learners who had more proficiency in English (Doabler et al., 2019).

Another study that utilized the data gathered from the ROOTS efficacy projects considered whether early mathematics skill affected the benefits gained by the students. The authors also considered whether the large group versus small group intervention differed in benefits for students (Clarke et al., 2019). The authors found that students who scored lower initially showed greater gains on two of the six outcome measures. They also found that the size of the intervention group did not produce different results (Clarke et al., 2019).

The aim of a study completed by Toll and Van Luit (2014) was to explore the effectiveness of an early numeracy intervention for kindergarteners who scored below average in numeracy. The early numeracy program under consideration was The Road to Mathematics. This program was devised to support children who are low performing in mathematics (Toll & Van Luit, 2014). The program utilizes over-rehearsal, small, task focused goals, and clear materials. The authors also considered whether the full version of the intervention significantly differed from a shortened version (Toll & Van Luit, 2014). Thirty-one schools from all four regions of the Netherlands participated in the study. Halfway through the school year 1,040 students were screened on an early numeracy test. For the purposes of this study a distinction was made between students scoring below the 50th percentile and the 25th percentile (Toll & Van Luit, 2014). All of the students who scored below the 50th percentile were matched into groups of three students who had comparable scores. Then, of the three one child was randomly chosen to participate in the intervention group and the other two were put into the control condition. After one year the children in the control group were once again matched, this time into a group of two, and one of each pair was placed in the shortened version of the intervention (Toll & Van Luit, 2014). The students who were in the intervention groups did not attend the math lessons in the regular classroom. The students were assessed using the Early Numeracy Test-Revised (Van Luit & Van de Rijt, 2009) at five time points. The pretest was given halfway through the first kindergarten year, then the students were assessed at the end of kindergarten, halfway through and at the end of the second kindergarten year and the post-test was administered halfway through first grade (Toll & Van Luit, 2014). At the time of the post-test the students were given a math achievement test and a non-verbal intelligence test (Toll & Van Luit, 2014). The authors found that the students in the intervention groups significantly outperformed the students in the control condition on both the post-test and on the follow up test. Interestingly, while the students who received a year and a half of the intervention outperformed the students who received a half of a year of intervention on the post-test, this trend was not sustained on the follow up test (Toll & Van Luit, 2014). The authors noted that the children who were in the full intervention group's scores, almost reached the scores of the students who scored above the 50th percentile at the midway point of the first year of kindergarten. They concluded that it might be possible for children at risk to catch up to their peers before first grade (Toll & Van Luit, 2014).

An eight-week number sense intervention that targeted low-income families emphasized whole number concepts such as counting, comparing, and manipulating sets (Dyson et al., 2013). The authors recruited kindergarteners from schools within a school district in the mid-Atlantic region of the United States. They specifically selected five schools which served low-income urban families. The total sample size was 121 and half were randomly assigned to the intervention group while the other half were assigned to the business-as-usual group (Dyson et al., 2013). The participants were given a pretest, a post-test, and a delayed post-test. At each test date all participants were given the Number Sense Brief (Jordan et al., 2010) and the Woodcock-Johnson III Tests of Achievement Form C Brief Battery: applied problems and calculation subtests (Woodcock et al., 2007). The intervention group attended 30 min sessions three times a week over an eight-week period (Dyson et al., 2013). The groups were small, only four students per instructor (Dyson et al., 2013). The intervention did not take the place of regular math instruction, it was carried out at a time when the students were not engaged in math or literacy instruction. The post-test occurred a week after the intervention and the delayed post-test occurred six weeks after that (Dyson et al., 2013). The activities that were included in the intervention included an activity that the authors called Magic number. This activity focused on the numbers 11 through 19 and place value. There was also a number recognition game, a number sequencing activity, verbal subitizing, activities encouraging finger use, activities that encouraged associating numeral to quantity, practice of the number plus (or minus) one, number comparisons, part-whole relationships, using counting to solve problems, and finally a number board game (Dyson et al., 2013). The results of this study were encouraging. The intervention group made greater gains on the number sense measure and on the Woodcock Johnson Calculation Subtest (Woodcock et al., 2007) than the control group and the effects held, although they diminished, six weeks after the intervention ended (Dyson et al., 2013). The authors noted that the intervention children, at post-test, were able to recognize larger numbers than were presented in their intervention, so, it seems that they were able to generalize what they learned. The intervention group showed a significant difference in growth in number knowledge, story problems, and number combinations (Dyson et al., 2013). The intervention group began the study below the control group in regard to the effectiveness of their strategy use, at the time of the delayed post-test there was not a difference between the two groups in this area (Dyson et al., 2013)

This study was repeated with a second cohort of students by the same authors and two more colleagues. In the second iteration a few things were modified (Jordan et al., 2012). The intervention was modified to align more closely with the Kindergarten Common Core State Standards. The instruction was modified such that some concepts were introduced earlier with the hope that this would lead to greater growth. The students were also exposed to more varied situations and contexts in terms of written calculations (Jordan et al., 2012). In the second iteration they also include a second control group in which there was a literacy intervention. The remainder of the methods mirrored the first study. They had a total sample size in the second study of 128 (Jordan et al., 2012). The intervention produced similar results as the first iteration and the language intervention control group did not differ from the business-as-usual control group on any math measures. When the authors controlled for initial skill level, the students in the number sense intervention performed better than either of the control groups on both the measures (Jordan et al., 2012). There was a large effect size on story problems at the delayed post-test (Jordan et al., 2012). The number sense group also demonstrated significant improvement in number combinations, number knowledge, and calculations compared to the control groups (Jordan et al., 2012).

Interventions Targeting Spatial Reasoning.

Several studies have considered whether interventions aimed at spatial skills can improve mathematical abilities. A meta-analysis of such studies conducted by Uttal et al., (2013) examined not only the size of spatial training effects but also the durability of such interventions and whether the training can transfer to other tasks. The authors used a variety of considerations to determine which studies they would include. Among those considerations they looked for the use of a mixed-effect model, the type of training, the duration of the training, and the method of training. Their search resulted in a total of 217 articles to be used in their meta-analysis (Uttal et al., 2013). The authors concluded that overall spatial skills are malleable, and training in spatial thinking is effective, durable, and can be transferred to other tasks (Uttal et al., 2013). They found that training produced an average effect size of 0.62. They also found that the magnitude of the training effects was similar for posttests that were given immediately after the training as for posttests that were given after a delay (Uttal et al., 2013). In terms of malleability, they found that training was most effective for participants who began with lower levels of spatial abilities (Uttal et al., 2013).

A study that looked at the effects of spatial training in younger students recruited students from Head Start facilities as well as students enrolled in private preschools in two northeastern states also found encouraging results (Bower et al., 2020). There were 187 children who participated in the study and they were classified as either high socioeconomic status or low socioeconomic status based on the level of education of the caregiver. All children completed a pre and post-test using a number of spatial assessments, a shape identification test, and a spatial vocabulary assessment, a mathematics abilities test, and they were given a general vocabulary assessment (Bower et al., 2020). There were three training conditions and a control group. Students were randomly assigned to one of the groups. Children in all three of the training groups attended five spatial training sessions which each lasted 10 min. The sessions took place over the course of about 5 weeks (Bower et al., 2020). The difference between the three training groups lay in the feedback of the trainers. One group received simple corrective feedback, one group received corrective feedback that was accompanied by spatial language, and the final group received corrective feedback that was accompanied by gesture (Bower et al., 2020). The authors found that while students who received the spatial training did improve their performance when compared to the control group, this effect was moderated by socioeconomic status. They found that only the low socioeconomic group benefited from the training (Bower et al., 2020). In terms of transfer, the authors found that the low socioeconomic status students who received training increased their performance on the mathematics assessment more than those who did not receive training (Bower et al., 2020).

Another study considering the efficacy of spatial training and mathematical abilities also provided training on a spatial task and then looked for effects on computation tasks (Cheng & Mix, 2014). In this study the 58 participants were predominantly middle-class children living in Michigan. All participants were given two spatial tests and one math test as a pretest. All participants participated in a 40-min session. For the students in the treatment condition this session consisted of mental rotation practice. For the students in the control group the session consisted of work on crossword puzzles (Cheng & Mix, 2014). These sessions were followed immediately by three post-tests. These post-tests were a mental rotation test created by the authors, the Spatial Relations Subtest of the PMA Math Test (Thurstone, 1974) and a math performance test that consisted of a set of 27 addition and subtraction problems (Cheng & Mix, 2014). The results indicated a significant difference between the spatial training group and the control group on both the Mental Rotations Test and the math test. There was not a significant difference on the Spatial Relations subtest (Cheng & Mix, 2014). Interestingly, the strongest difference was in missing term problems (e.g., 3 + ____=7) (Cheng & Mix, 2014).

Math Games as an Intervention

A specific subset of intervention that is of particular interest to this paper is the use of math games as an intervention to improve math outcomes for early elementary students. A study that furthered the research regarding the intervention Building Blocks and compared it to an intervention that combined Building Blocks with the scaffolding of play (Clements et al., 2020). The authors of the Building Blocks curriculum and the authors of a play-based curriculum Tools of the Mind collaborated to synthesize the two curricula. The Tools of the Mind curriculum is focused on scaffolding dramatic and make-believe play with the intention of developing executive functioning (Clements et al., 2020). A total of 248 classrooms participated in the study and they were randomly assigned to one of three conditions. The first condition consisted of the Building Blocks curriculum, the second condition was Building Blocks and Tools of the Mind, and finally there was a business-as-usual group (Clements et al., 2020). All teachers who participated in one of the intervention groups were given training in either only Building Blocks or both curricula. The students were assessed at the beginning of the preschool year, at the end of the preschool year, and at the end of kindergarten. The assessments included the Tools for Early Assessment of Mathematics (Clements & Sarama, 2011) the mathematics section of the direct cognitive child assessment used in the Early Childhood Longitudinal Study-Birth EF, an assessment of inhibitory control, working memory, and phonological processing as well as measures of oral language (Clements et al., 2020). The results were not encouraging for the Tools of the Mind curriculum although they supported the earlier results of the Building Blocks curriculum. The group in which students were exposed to Building Blocks and Tools of the Mind was not statistically different from the business-as-usual group. The Building Blocks only group outperformed the business-as-usual group in math achievement (Clements et al., 2020).

Other research has directed the play interventions towards the use of mathematics and specifically the building of number sense. One such study conducted in France considered the efficacy of a software program that they created called "The Number Race". The game was designed to focus on core aspects of number sense (Wilson et al., 2009). The Number Race focused on three main principles: an emphasis on number sense, linking understanding of non-symbolic and symbolic representations of numbers, and increasing understanding and fluency for basic addition and subtraction facts (Wilson et al., 2009). The 53 participants were between the ages of 4 and 6 and were enrolled in their final year of kindergarten. They all attended one of two schools which were located in areas associated with difficult social and economic conditions (Wilson et al., 2009). A reading software was used as a control. All the students were given a pre-test. One of the classrooms utilized the math software for the first half of the study while the other used the reading software. At the end of this time the students were tested. Then, the classrooms switched software for the second half of the study. Finally, all students were given a post-test (Wilson et al., 2009). All the students in each group participated in six 20 min sessions with the math software and four 20 min sessions with the language arts software. The written test that was administered at each testing session was focused on number sense. It included written and verbal symbolic numerical comparison tasks, non-symbolic comparison tasks, both verbal and object counting, and addition (Wilson et al., 2009). The results were promising. The authors found that the math then reading group had significantly improved scores on the symbolic numerical comparison tasks between the pretest and the second testing session and these improvements were still present 6 weeks later at the third testing session. But they did not see significant differences on the non-symbolic numerical task (Wilson et al., 2009).

Another study which mainly utilized games involving dice also found promising results (Baroody et al., 2009). This study was interested in evaluating the potential of two computer programs in promoting kindergarten’s fluency with basic addition problems. The sample consisted of 28 kindergarten students who were identified as being in the bottom 25th percentile of mathematics achievement as measured by the Test of Early Mathematics Ability, 3rd Edition (TEMA-3; Ginsburg & Baroody, 2003). This study involved two stages (Baroody et al., 2009). The first stage included games with dice and lasted 10 weeks. The second stage had two groups, both of which were focused on mental addition strategies. One of the groups was exposed to n+1 or 1+n problems and the other group was exposed to doubles. The second stage lasted for 9 weeks. In both sessions participants participated in the intervention twice a week in 30 min blocks (Baroody et al., 2009). The stage 2 mental addition intervention consisted of 10 practice items, a break, and 10 more practice items. The child was asked to solve a problem and then the trainer or the computer provided feedback. If the response was incorrect, they were instructed to try again, if they were incorrect a second time, they were asked to use a manipulative (either physical or virtual) to help them solve the problem (Baroody et al., 2009). The team used the TEMA-3 (Ginsburg & Baroody, 2003) and a Mental-Addition Test that was created for the project to assess the students (Baroody et al., 2009). The authors found that while the doubles group more than doubled their fluency scores by the time of post-test, the n+1/1+n group increased their score by about 6 times what they were at pretest (Baroody et al., 2009). Unfortunately, the authors did not report results for stage I of this study. Stage I was seen as building the prerequisite understanding for stage II (Baroody et al., 2009).

Number Worlds is another game-based program that was created to increase mathematical understanding in young children (Griffin, 2004). Several studies evaluating the effectiveness of the program for children from low socioeconomic backgrounds have found that the program has led to significant gains in both number sense and conceptual knowledge of number when compared to control groups (Griffin, 2004).

An elegant study consisted of two experiments considered the efficacy of a linear board game to improve number knowledge in children from low-income backgrounds (Ramani & Siegler, 2008). One hundred twenty-four preschoolers from 10 Head Start centers in an urban area participated. Each child was randomly assigned to either a number board condition or a color board condition (Ramani & Siegler, 2008). The intervention consisted of four 15 to 20 min sessions over a 2-week period. During this time, they were able to play the game 20 times. Both board games were the same size, had the same title, and had 10 equal sized squares lined up horizontally (Ramani & Siegler, 2008). The only difference between the two boards was that in the number board condition the squares were labeled from 1 to 10. Each game had a spinner. The number board game spinner was labeled with a 1 on one half and a 2 on the other. The color board spinner had colors that matched the colors on the board. Students in the number board group would spin the spinner and move the number that they spun while saying the names of the numbers that they were moving over or onto. The color board group would say the names of the colors that they passed (Ramani & Siegler, 2008). The students were given a pretest during session one before they played the games and on the fourth session after they played the game. The 5th session took place nine weeks after the fourth session and the students were retested at this session but did not play the game (Ramani & Siegler, 2008). The authors found that the students who played the number board game made significant gains in the number identification tasks while the color board game participants made minimal gains. These results were replicated when the authors considered magnitude comparison accuracy and counting skill, and number line estimation. The number board game participants made considerable gains and the color board game participants demonstrated only slight gains (Ramani & Siegler, 2008). Notably, the gains in all four tasks that were seen at the immediate post-test remained significant at the delayed post-test nine weeks later (Ramani & Siegler, 2008).

Experiment 2 of this study is also of interest to the current paper in that they considered whether children’s exposure to board games, cards, or video games would be correlated with stronger mathematical understanding (Ramani & Siegler, 2008). The authors asked the children who participated in Experiment 1 about their experiences playing board games, cards, and video games and then used the results of the pre-test to examine the relationship between game playing and mathematical understanding (Ramani & Siegler, 2008). The authors found a large difference in the number of experiences reported by children from different income backgrounds. For example, 80% of children from middle income families reported playing one or more board games outside of school while only 47% of the Head Start participants did (Ramani & Siegler, 2008). Examining the number of board games that the children stated that they had played was positively correlated with their pretest scores of numerical knowledge on all four tasks. This was not the case for card games or video games which were only correlated with one of the tasks apiece (Ramani & Siegler, 2008). The authors found that children's numerical knowledge varied depending on the number of contexts that they reported having played board games. The more contexts that the children reported having played board games the better they performed at comparing numerical magnitudes and they generated number line estimates that were more linear (Ramani & Siegler, 2008). They did not find any relationship between the number of contexts for playing cards or video games and numerical knowledge (Ramani & Siegler, 2008). The authors considered the game Chutes and Ladders specifically because a high percentage of children named it and because they expected that the linear nature of the game might lead to positive outcomes in mathematics. They found that playing the game Chutes and Ladders was correlated with four out of the five measures of numerical knowledge (Ramani & Siegler, 2008).

A study that closely mirrored Experiment 1 of the 2008 study by Ramani and Siegler found similar results. Whyte and Bull (2008) utilized three experimental groups, a linear number group, a linear color group, and a nonlinear number group. Their study included 45 preschool children from middle and working-class backgrounds who were recruited from four nursery schools in Scotland. The children participated in six 25-min sessions. The first session consisted of a pretest and the last session consisted of a post-test (Whyte & Bull, 2008). The assessments were created to assess counting abilities, numerical comprehension, and numerical estimation skills. The linear number group game board closely resembled the board from the Ramani and Siegler (2008) study other than that each week another length of board was added to the game. So, the first week the board included the numbers from 1 to 10 and the following week 11-20 were added. The game was played in the same manner as the Ramani and Siegler game. The linear color group's board was also very similar to the color board in the Ramani and Siegler (2008) study. But it had additional pieces that were identical to the first board that were added to the board each week (Whyte & Bull, 2008). The final group's game consisted of cards that had pictures of different quantities of apples. The number of apples was written on the opposite side of the card. The first week the group used the cards that had between 1 and 25 apples, the second week they added the cards that had 26 to 50 apples and so on until they had cards with 1 to 100 apples in the last session. To play the game two cards were picked up and the children had to identify which card had the most apples (Whyte & Bull, 2008). Both numerical groups showed significant growth in number naming, counting abilities, and performance in their ability to recognize and name Arabic symbols (Whyte & Bull, 2008). The one area in which the linear number growth showed significantly greater increase than the non-linear number group was in their ability to recognize and name Arabic symbols. The authors did not find a significant difference over time for the linear color group (Whyte & Bull, 2008).

The Home Environment and Intervention

The interventions thus far have occurred in school settings, some in elementary school and others in preschool programs. Given the research demonstrating that the home numeracy environment plays an important role in children's mathematical abilities (LeFevre et al., 2009; Ramani et al., 2015, Galindo & Sonnenschein, 2015; Levine et al., 2010; Yildiz et al., 2018), it is not surprising that there have been several studies focusing on interventions that take place in the home environment.

A qualitative study that investigated the effects of an informal use of tablet-based fact practice found that students enjoyed practicing mathematics using the tablet (Stacy et al., 2017). The authors partnered with three different organizations to provide tablets and access to a tablet-based math practice app in four different settings. All data was collected through observation and surveys (Stacy et al., 2017). They noted that in all settings, and in both one-time events and year-long programs the students were willing to practice and often highly engaged with the math practice. They found that they did not have behavioral problems and that the students preferred the tablet to paper and pencil math practice activities (Stacy et al., 2017). This study highlights the benefits of utilizing activities and methods that are enjoyable to students and leveraging them to develop mathematics skills. One such way to do this is through the use of math games with students as an intervention.

A study looking at an early mathematics intervention with a school and a home component, considered whether the intervention had a positive impact on children's mathematical understandings and also to closely consider the informal mathematical knowledge of pre-kindergarteners from both low- and middle-income families (Starkey et al., 2004). Participants were recruited from participating pre-schools which served either low-income or middle-income families. The authors utilized a successive cohort design and the study examined the subsequent data from 163 students (Starkey et al., 2004). Students in the intervention group were assessed using the Child Math Assessment, an assessment developed by the authors for this particular study, as a pretest before the intervention began and then a post-test in the spring after the intervention was completed. The children in the control group were given the Child Math Assessment in the Spring only (Starkey et al., 2004). The intervention consisted of the program Pre-K Mathematics. The teachers were given professional development for 5 days in the summer and 4 days in the winter to learn to implement the classroom component of the intervention. The at home portion of the intervention consisted of the children and parents attending three home mathematics classes over the course of the year (Starkey et al., 2004). The classes consisted of a presentation of four mathematics activities with instruction as to how the parents should engage with their children while doing the activities. The families were also given materials and guide sheets for engaging in the activities at home with their children (Starkey et al., 2004). The results indicated that the children had gained mathematical knowledge as a result of the intervention. The Child Math Assessment scores increased for both low- and middle-income students who participated in the intervention (Starkey et al., 2004). The effect sizes were large for each group. But they also found that the scores of the low-income intervention students' scores increased more, relative to their starting points, than did the scores of the middle-income intervention students (Starkey et al., 2004). The authors found that the spring low-income intervention students' scores were similar to the middle-income control group scores (Starkey et al., 2004).

A study which utilized a math app, Bedtime Learning Together, aimed to determine whether increasing opportunities for parents and their children to discuss mathematics at home could improve children's math achievement (Berkowitz et al., 2015). The authors were also interested in whether the children of adults who were apprehensive about math, and therefore tend to engage in low quality math input with increased opportunities for math input, would especially improve in their mathematical understanding (Berkowitz et al., 2015). The sample consisted of 587 first-grade children and their families. The participants were divided into two groups and each group was assigned to read either math or a reading passage and to answer math or reading comprehension questions that went along with the reading several times a week over the course of a year. All material was delivered via the app. The math group was oversampled, as it was their main focus (Berkowitz et al., 2015). Each of the child's math abilities was assessed both before and after the intervention. The authors found that, for the math group only, the more times that the parents and children used the app the higher the children's math achievement at the end of the year (Berkowitz et al., 2015). They also found that children who used the app often, which they defined as more than one standard deviation above the mean of app use, demonstrated approximately 3 months of achievement above the students who used the reading app often. Finally, they found that the children of parents who scored as highly anxious who were placed in the math group outperformed the children in the reading group by almost 3 months by the end of the year (Berkowitz et al., 2015).

The Home Environment and Game Based Interventions

In an experiment intended to examine the efficacy of providing low-income Head Start families with card games to play at home in improving the mathematical knowledge of the children, the authors developed three goals (Ramani & Scalise, 2020). The first goal was to consider the effectiveness of the card games in improving math knowledge, the second was to investigate the frequency of playing the card games at home, and the third was to determine how parents supported the children while playing cards (Ramani & Scalise, 2020). Thirty-nine children participated in the study and all children were given a pretest which measured numerical knowledge and shape knowledge. At that point the children were randomly assigned to either a numerical magnitude comparison game or a shape and color matching game (Ramani & Scalise, 2020). The participants were asked to play the game assigned to them twice a week for 15 min each time. The duration of the intervention was six weeks. The families were asked to audio record themselves while they played and to complete a log of when they played the game (Ramani & Scalise, 2020). At the end of the six-week intervention period the same measures used at pretest were administered and the audio recordings were transcribed and coded for the type of help provided to the children (Ramani & Scalise, 2020). The authors found that while the participant who played the shape and color game did significantly improve their performance on the assessment requiring students to name shapes, playing the numerical magnitude card game did not significantly improve the children's performance on the numerical knowledge measures (Ramani & Scalise, 2020).

A study which aimed to explore whether an intervention meant to increase the intentionality in which parents engage in numeracy-based activities with their children and the children's subsequent performance found that it is possible to improve mathematical knowledge through intervention that addresses the home environment (Niklas et al., 2016). In this study 113 participating preschool children were given assessments of their numerical abilities and the primary caregivers were given surveys regarding the family characteristics and the home learning environment (Niklas et al., 2016). The parents were invited to participate in a parent evening. Of the 113 participants, parents of 37 of the children attended the parent evening. At the parent evening the importance of promoting children's numeracy skills in the home was described, the parents were provided with suggestions as to how to support skills in a purposeful manner, and the parents were invited to participate in an individualized session with the children that included playing a game with dice. All 37 of the parents who attended the evening session accepted this invitation (Niklas et al., 2016). During these sessions the parent, child, and a member of the research team played a dice based counting game that the child was invited to keep. The parents were provided with coaching on how to support their children's learning of counting principles (Niklas et al., 2016). The design of this study was not experimental in that the 37 families who attended the parent evening and the game playing session were considered to be the intervention group and the 76 families who did not were considered to be the control group. While children in both groups improved in their mathematical abilities across the two dates of assessment, the children in the intervention group had greater gains in their abilities, the authors reported a medium effect size for this comparison (Niklas et al., 2016).

A study that considered the effectiveness of utilizing a board game at home as an intervention was done in two separate studies with students from Baltimore. (Sonnenschein et al., 2016). The authors' second and third research questions asked whether parents would adhere to the specific count on procedure when playing with their children and whether parents' beliefs about children's math activities and children's home math engagement would relate to whether or not the parents would comply with the math intervention. The first study was conducted with 84 students from a Head Start program. In this study the children were randomly assigned into one of three groups. The first group was given the game Chutes and Ladders and the parents were instructed in the count-on procedure used by Ramani and Siegler (2008), this group was considered the experimental group. The second group was given the game Chutes and Ladders with the standard game instructions and considered the numeric control, and the final group was given the game Candy Landy and considered the control group (Sonnenschein et al., 2016). The authors reported that only 52% of the children returned logs specifying how long and with whom the children played the games. They also found that while the children's scores significantly increased from pretest to posttest for counting and numeral identification the changes were not different across groups (Sonnenschein et al., 2016). Following the first study the authors conducted a number of focus groups with the participants. Following these groups, they began Study 2. Study 2 had 98 participants, also from Head Start facilities in Baltimore (Sonnenschein et al., 2016). The second study was very similar to the first although there were changes made to the groups. There were four groups, a Chutes and Ladders with a sticker chart group, a Chutes and Ladders with child training group, Chutes and Ladders with stickers and child training, and a no-game control condition. Parents were asked several questions about math socialization at home. The children were assessed in their math skills in the same manner as they were assessed in the first study (Sonnenschein et al., 2016). The authors reported a significant increase in children's performance regardless of condition. They also found that there was a significant relationship between number line estimation and performance for the children who were in the stickers with training group while the control group showed a decrease in accuracy from pre to post-test (Sonnenschein et al., 2016).

Literature Review Conclusion

Research has consistently demonstrated that young children's early mathematical understandings are predictive of those children's later mathematical abilities (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). Of these early understandings there is evidence that counting and numeracy (Aunio & Niemivirta, 2010; Aunola et al., 2004; Nelson & McMaster, 2019; Nguyen et al., 2016), general number sense (Geary et al., 2007; Jordan et al., 2007), and spatial reasoning (Holmes et al., 2008; Lauer & Lourenco, 2016; Lowrie et al., 2016) are especially useful in promoting later mathematics achievement. All populations do not share the same probability of entering school unprepared for the mathematical demands of formal schooling (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). The home learning environment plays an important role in the development of children's mathematical understandings (Galindo & Sonnenschein, 2015; Levine et al., 2010; Ramani et al., 2015; Yildiz et al., 2018). But, the promising news is that there is research to suggest that interventions can be effective in mediating this problem (Nelson & McMaster, 2019; Mononen et al., 2014). There has been research into the idea of using math games to improve mathematics achievement and this research suggests that this method can be effective (Baroody et al., 2009; Griffin, 2004; Ramani & Siegler, 2008; Whyte & Bull, 2008; Wilson et al., 2009).

It would be of interest to know whether a math game intervention that was inexpensive and easy to implement through the public schools and completed at home could address the inequity in mathematical knowledge of kindergarteners from low socioeconomic status backgrounds. Building on the understanding that number sense and numeracy skills have been found to be particularly helpful in building mathematical understanding, the games address these skills specifically. Further, based on this research it seems that it is important to intervene early, as early knowledge and trajectories are predictive of later achievement (Watts et al., 2014). This study would be particularly important in that part of the goal would be to implement the intervention in a way that would be easily replicated in any school, even when the school had few resources. The study by Ramani and Siegler (2008), while very powerful in terms of demonstrating the possible efficacy of a game-based intervention, utilized a researcher to engage with the children one on one for every instance of the intervention. This is not a realistic intervention in most schools. Therefore, it is unlikely to be adopted in a wide variety of schools as a means of improving the long-term outcomes for children from disadvantaged backgrounds. The current study aims to show that a game-based intervention can be both effective, inexpensive, and easy to implement.

CHAPTER THREE: RESEARCH METHODS

The primary purpose of this study is to determine whether playing a math game at home can improve kindergarteners' performance on a math test of numeracy skills and understanding. The secondary purpose of the study is to examine whether the effect of playing math games is influenced by socioeconomic status. The study will also consider whether families who report that their children play more games at home will score higher on the pre-test than students whose families report less playing of games at home.

The following research questions will be investigated:

Research Question #1

Will change in performance on a mathematics assessment be influenced by playing a math game at home?

The following hypotheses will address this research question:

H1: Playing a math game at home 20 times in a two-week period will lead to increased scores on a math test.

H01: Playing a math game at home 20 times in a two-week period will not lead to increased scores on a math test.

The independent variable is the playing of a math game at home. The dependent variable is the student scores on a math test.

Research Question #2

Will students from low socioeconomic backgrounds improve their math scores more than students from high socioeconomic backgrounds after playing a math game at home?

The following hypotheses will address this research question:

H2: Students from low socioeconomic backgrounds will improve their math scores more than students from high socioeconomic backgrounds after playing a math game 20 times at home for a two-week period.

H02: Students from low socioeconomic backgrounds will not improve their math scores more than students from high socioeconomic backgrounds after playing a math game 20 times at home for a two-week period.

This question considers whether socioeconomic status is a potential moderator of the relationship between the independent and dependent variable. The independent variable is the playing of a math game at home. The dependent variable is the student scores on a math test.

Research Question #3

Is initial math performance related to parent-reported home learning activities?

H3: Reported amounts of game playing at home will be correlated to higher scores on a math test.

H03: Reported amounts of game playing at home will not be correlated to higher scores on a math test.

This question investigates a potential correlation between the two variables game playing at home and math performance.

Methods

<u>Participants</u>

All kindergarten students at Aspen Elementary School were invited to participate in this study. All families were contacted by phone to inform them about the study, invite them to ask questions, and advise them that a form would be coming home in their kindergarten's backpack the following school day. A consent form was sent home with all students by their kindergarten teacher. After one week, any student who had not returned the form took a second form home. There were 57 students enrolled in one of four kindergarten classrooms at the time of the study, and of those, 35 returned consent forms. Demographic information regarding the two groups is shown below in Table 1.

Table 1 Comparison of General Population and Students Who Returned Consent Forms

Demographic Information	Consent Form Status	
	35 Students who returned consent forms	22 Students who did not return consent forms
Native Language	40% Native Spanish Speaking	77% Native Spanish Speaking
Gender	49% Male 51% Female	59% Male 41% Female

Clearly, there was a higher percentage of native Spanish speaking students who did not turn in their consent forms. Aspen Elementary School is a dual immersion school. So, it has a much higher percentage of Hispanic students than does the district as a whole. The district reports that 44% of the students are Hispanic. The percentage of native Spanish speaking students who participated in the study is closer to this percentage.

One notable difference between the students who turned in their consent forms and those who did not was the classroom teacher. There are four kindergarten classes. Eighty percent of students in one of the classrooms turned in their consent forms, 46% of another, 47% of the third, and finally 71% of the students in the fourth classroom turned in their consent forms. A possible explanation for this discrepancy is that some teachers probably have better procedures in place for getting papers home to parents. But, given that the students are randomly assigned to the kindergarten classroom this should not have an effect on the results of the study.

Of the 35 students, four students reported that they had forgotten to play the game. One stated that he had only played a little. Three students were absent from school the week the post-test was administered. This left a total of 28 participants for the game intervention portion of the study. Five of the participants who were eliminated from the final sample were in the control group, two were in the intervention group. All 35 of the participants were given the pre-test and had completed home surveys and so were included in the portion which considered reported game playing in the home and the pre-test results. Maternal education level was used to classify students as middle or high-income and low-income. Given that this study was completed during the COVID pandemic free and reduced lunch data was not available. All school aged children during this time were provided with free breakfast and lunch. Sirin (2005) argued that there was general agreement on the definition of socioeconomic status presented by Duncan and Featherman (1972). In this definition parental income, parental education, and parental occupation are considered the three main indicators of socioeconomic status (Duncan & Featherman, 1972). Given this definition, it was determined that maternal education would be an appropriate measure. Participants who reported a maternal education completion of high school or less were put into the low socioeconomic status group. Participants who reported maternal education of college or an advanced degree were placed in the middle or high-income group. Eighteen of the students were classified as low socioeconomic status and 10 were classified as medium or high socioeconomic status.

Table 2 Demographic Characteristics of Intervention Group and Control Group

	Intervention group (15 students)	Control Group (13 students)
First Language	Spanish: 53% English: 47%	Spanish: 31% English: 69%
SES	Mid to High: 33% Low: 67%	Mid to High: 38% Low: 62%
Gender	Female: 60% Male: 40%	Female: 46% Male: 54%

Design

Half of the high or middle SES students (*n*=13) and lower SES students (*n*=22) were randomly assigned to a treatment group or a control group. These conditions are described below. Students in both groups will be tested prior to the intervention (pretest) and then again after the intervention (posttest). Thus, this study used a 2 (group: intervention versus control) x 2 (SES: higher versus lower) x 2 (time: pretest versus posttest).

Setting

The school in this study is located in a rural community. The district has an enrollment of 3,160 students from Pre-Kindergarten through 12th grade. The district ethnicity distribution is 52% White, 44% Hispanic, and 4% other. Nineteen percent of students are classified as English Learners. In the year prior to this study, before COVID the district had 32% of students who received free or reduced lunch. Aspen Elementary specifically is a dual immersion magnet school and each classroom has approximately half native Spanish speaking students and half native English-speaking students. As such, it is not a neighborhood school. Any student living anywhere in the district may attend the school although there is only bussing provided for a segment of the district. There are two regular elementary schools within the area in which bussing is provided. This means that students at Aspen Elementary are self-selected. The families decided to send their children to a dual immersion school. The school has a total enrollment of 389 students. The school receives Title 1 money. At the time of the study, due to COVID 19, students were attending school only four days a week, Monday through Thursday.

Treatment

All participating families were called the weekend before the game was sent home. At this point they were given the survey. They were also advised that the game would be coming home on the following Monday. The instructions in terms of how many times they should play the game, how long they had to play the game, and that they should help their children to record how many times they played the game on the sticker chart. It was also explained to them that the children could play the game with anyone, a parent, a sibling, a friend, or any other family member. Then, half of the students in each socioeconomic group were randomly assigned to the control group and half to the intervention group. Each child took home a game and a sticker chart with 20 spaces and stickers. They were asked to play the game 20 times and to put a sticker on the chart each time to keep track. They were told that they did not have to play the game every day. But they should play the game 20 times. The game was very short, it can be played in 10 minutes, so it is feasible for the students to play more than once in a day. The instructions were relayed verbally to the students and parents and were also in the packet that was sent home containing the game and the materials needed to play the game. At the end of the 2-week period the students brought the sticker chart back to school. If the student returned a completed sticker chart the student qualified for one entry into a lottery. The prizes were store bought math games. The lottery was intended to make the students feel incentivized to bring the sticker charts back. As students were given the post-test they were asked about the frequency that they played the game.

The intervention group was given a game based on a game created by the Developing Mathematical Thinking Initiative and the game utilized in the study by Ramani and Siegler (2008; see Appendix A). This game was selected because it is very similar to the game used by Ramani and Siegler (2008), but it is slightly more challenging. The game used in the study included a bar model from 0 to 15 while the Ramini and Siegler (2008) game only included 0 to 10. Also, the Ramini and Siegler (2008) game used a spinner with one and two as possible options while the game used in the study utilized a die. The Ramani and Siegler (2008) study utilized preschool students as participants and the current study focused on kindergarteners. It seemed appropriate that the game should be slightly more challenging yet very similar. The game is played with two players. Each player has a bar separated into 15 spaces which are numbered. The players begin on 0. They roll a die and move forward the number that the die lands on. The first player to reach 15 wins. The players must land on 15 exactly to win.

The control group received a game that looks very similar to the math game, but it is a sight word game (see Appendix A). The board is exactly the same except that the boxes have one of five sight words inside. The players draw a card from a stack of cards that has one of the 5 sight words. They may move forward to the next matching word. The winner is the player that lands on the last word in the bar first. Alturas is a dual immersion school so the students will have the English version on one side and the Spanish version on the other. Their sticker charts were the same.

Everything to play the games was sent home in plastic folders with the instructions in both English and in Spanish. The students were given two-weeks to play the games at their homes. At the end of this time students were reminded to bring their sticker charts back to school.

Measurement

The Primary Math Assessment from the Developing Mathematical Thinking Initiative was administered for both the pre and post-test. This was a distal measure in terms of the intervention. This measure was selected because it is a measure already being used in the district. The kindergarten teachers had not used the assessment during this particular school year because of time and resource constraints due to COVID. So, in keeping with the idea of creating an intervention that would be inexpensively recreated I chose to use a measure that was already purchased by the district. The measure took approximately two-weeks to complete at pre-test because of the additional time required to gain verbal assent. The post-test was completed over a one-week period. Students receive a total of seven different scores. They receive a score for sequencing, facts, relational thinking, interpreting context, measurement, spatial reasoning, and an average score.

Parents were also surveyed over the phone. The survey asked for the highest education level of the mother or other caregiver. This information was used as a proxy for socioeconomic status. The form also asks four questions pertaining to the frequency that the child plays games at home. The questions and scale used for measurement were adapted from a survey used in a study conducted by Niklas et al. (2016; see Appendix B).

Instruments

The students were given the Primary Mathematics Assessment (PMA; Brendefur & Strother, 2010) as both a pre and post-test. The Primary Mathematics Assessment is designed to be used with students in grades kindergarten through second. It examines six dimensions of mathematics understanding with the goal of identifying students at risk for poor math outcomes (Brendefur et al., 2015). The assessment consists of a screener (PMA-S) and a diagnostic test (PMA-D) that is meant to be utilized with students who are identified as at risk on the screener (Brendefur et al., 2015). The PMA-S was the only test administered in this study. The six measures of mathematics measured by the Primary Mathematics Assessment are number sequencing, operations (number facts), contextual problems, relational thinking, measurement, and spatial reasoning (Brendefur et al., 2015). In the number sequencing portion of the test the students are given a series of numbers and asked to identify the missing number or to identify the number representing the largest amount. The operations portion asks the students to add or to subtract. The contextual problems provide a contextual addition or subtraction problem. For example, there are eight birds in a tree, five of the birds fly away. How many birds are left? The relational thinking portion of the test includes, for example, an equation in which there are addition sentences on either side of an equal sign with one digit replaced with an empty box. The students are asked to determine which number should go into the box to make the statement true. The measurement section includes questions that give an unit and then that unit is iterated beside a picture and the students are asked how many units tall the item is. Finally, the spatial reasoning portion asks the students to determine which picture would best fit into an empty space in another picture. The authors of the Primary Mathematics Assessment found that the Cronbach's reliability for relational thinking was greater than .80, and the Cronbach's reliability for measurement was greater than .81. The other dimensions had reliabilities ranging from 0.74 for spatial reasoning to 0.78 for sequencing (Brendefur et al., 2015).

The survey that was used to investigate game playing in the home environment was adapted from Niklas et al., (2016). The scale was copied exactly from their survey and four of their questions were used for the sake of brevity given that this was not the main focus of the present study. The survey is shown below in both English and Spanish.

Child's name: ___________________________

Highest education level of the mother or other caregiver:
Please circle the appropriate response

Less than high school   High school   Bachelor's Degree   Advanced Degree

How frequently does your child play board games?

☐ several times a week ☐ once a week ☐ once or twice a month ☐ less frequently ☐ never

How often does your child play games that involve dice?

☐ several times a week ☐ once a week ☐ once or twice a month ☐ less frequently ☐ never

How often does your child play games that require him or her to count?

☐ several times a week ☐ once a week ☐ once or twice a month ☐ less frequently ☐ never

How often does your child play games that require him or her to do simple sums?

☐ several times a week ☐ once a week ☐ once or twice a month ☐ less frequently ☐ never

Figure 1 English Version of the Survey (adapted from Niklas et al., 2016).

Nombre de su hijo/hija: ___________________________

El nivel de educación más alto de la madre u otro cuidador:

Por favor, encierre en un círculo la respuesta apropiada

Menos que el secundario el secondario la universidad Diploma Avanzado

¿Con qué frecuencia juega su hijo a juegos de mesa?

varias veces a la semana ☐ una vez a la semana ☐ una o dos veces al mes ☐ con menos frecuencia ☐ nunca

¿Con qué frecuencia juega su hijo a juegos de dados?

varias veces a la semana ☐ una vez a la semana ☐ una o dos veces al mes ☐ con menos frecuencia ☐ nunca

¿Con qué frecuencia su hijo juega a juegos que requieren que cuente?

varias veces a la semana ☐ una vez a la semana ☐ una o dos veces al mes ☐ con menos frecuencia ☐ nunca

¿Con qué frecuencia su hijo juega a juegos que requieren que haga sumas simples?

varias veces a la semana ☐ una vez a la semana ☐ una o dos veces al mes ☐ con menos frecuencia ☐ nunca

Figure 2 The Spanish Version of the Survey (adapted from Niklas et al., 2016)

CHAPTER FOUR: RESULTS

The size of the sample was small in this study, especially when dividing the sample into treatment and control groups and low SES and medium and high SES. The small sample size raised concerns about the assumption of normality of data; therefore, I chose to use non-parametric statistics for all tests.

Research Questions 1 and 2 examined the change in performance from pretest to posttest. To address these questions, a change in math performance was computed for each participant by subtracting the pretest score from the posttest score. Change in math performance was the dependent variable in these analyses. Descriptive statistics on pretest and posttest math performance for the groups by SES are reported in Table 3. It is important to note that students completed pretests the week that they came back to school four days a week after being at school for only two days a week for most of the school year. This, at least partially explains the strong growth on the math assessment over a two-week period.

Table 3 Pretest and Posttest Math Performance for Groups and Socioeconomic Status

	Socioeconomic Status		Whole Group
Treatment	Medium and High SES	Low SES	
Intervention Group	**Pretest** Mean: 37.00 Standard Deviation: 12.84	**Pretest** Mean: 32.00 Standard Deviation: 14.42	**Pretest** Mean: 33.67 Standard Deviation: 14.11
	Posttest Mean: 47.00 Standard Deviation: 4.73	**Posttest** Mean: 44.30 Standard Deviation: 15.77	**Posttest** Mean: 45.20 Standard Deviation: 13.22
Control Group	**Pretest** Mean: 46.00 Standard Deviation: 28.16	**Pretest** Mean: 35.75 Standard Deviation: 23.62	**Pretest** Mean: 39.69 Standard Deviation: 25.94
	Posttest Mean: 58.40 Standard Deviation: 23.69	**Posttest** Mean: 48.13 Standard Deviation: 20.47	**Posttest** Mean: 52.08 Standard Deviation: 22.33

Research Question #1: Will change in performance on a mathematics assessment be influenced by playing a math game at home?

For each participant, a change in math performance was computed by subtracting the pretest score from the posttest score on the total score on the Primary Math Assessment. Change in math performance, the dependent variable in the analysis, was compared across the intervention group and the control group using Mann-Whitney test. There was no significant difference in the change of math performance between the intervention group and the control group, $U = 92.50$, $p = 0.82$. This suggests that the intervention did not have a significantly different effect on change in math performance.

Separate analyses were also conducted on two subsections of the PMA. For each participant, a change in math performance was computed by subtracting the pretest score from the posttest score on the sequencing portion of the Primary Math Assessment. The Mann-Whitney test revealed no significant difference in change in sequencing performance, $U = 84.50$, $p = 0.56$. This suggests that the intervention did not have an effect on the change in scores on the sequencing portion of the test.

Change in the operations portion of the PMA was also compared across groups. The Mann-Whitney test revealed that there was not a significant difference in change operations performance, $U = 85.50$, $p = 0.59$. This suggests that the intervention did not have an effect on operations performance.

Research Question #2: Will students from low socioeconomic backgrounds improve their math scores more than students from high socioeconomic backgrounds after playing a math game home?

Here the focus was on change in performance for students in the intervention group. Specifically, intervention low SES students were compared to intervention high and middle SES students. Change in math performance (total score on the PMA) was compared across the SES groups using a Mann-Whitney test. For students in the intervention group, there was no significant difference in their improvement, ($U = 22.50$, $p = 0.77$). This suggests that the intervention did not work differently for low SES students and Medium-High SES students.

Research Question #3: Is initial math performance related to parent-reported home learning activities?

To examine the relation between game playing and math performance. Survey responses were correlated with pretest math performance (total score on the PMA). The survey responses are ordinal data; therefore, for each survey question a Goodman-Kruskal gamma correlation (an ordinal measure of association) was computed. The percentage of parents who gave each response to the survey are reported in Table 4.

Table 4 **Responses to Survey Questions**

	Survey Question			
Scale	How frequently does your child play board games?	How often does your child play games that involve dice?	How often does your child play games that require him or her to count?	How often does your child play games that require him or her to do simple sums?
4- several times a week	4/35 11%	1/35 3%	10/35 29%	7/35 20%
3- once a week	14/35 40%	8/35 23%	8/35 23%	7/35 20%
2-once or twice a month	13/35 37%	8/35 23%	10/35 29%	12/35 34%
1- less frequently	1/35 3%	6/35 17%	5/35 14%	3/35 9%
0- never	3/35 9%	12/35 34%	2/35 6%	6/35 17%

Survey Question 1. The first survey question asked "How frequently does your child play board games?" The Goodman-Kruskal gamma correlation between frequency of playing board games and pretest math performance was not significantly different than zero ($G = 0.11$, $p = 0.53$). Thus, frequency of playing board games was not related to pretest math performance.

Survey Question 2. The second survey question asked, "How often does your child play games that involve dice?" The Goodman-Kruskal gamma correlation between frequency of playing dice games and pretest math performance was not significantly different than zero ($G = 0.01$, $p = 0.97$). Frequency of playing dice games was not related to pretest math performance.

Survey Question 3. The third question asked, "How often does your child play games that require him or her to count?" The Goodman-Kruskal gamma correlation between frequency of playing counting games and pretest math performance was not significantly different than zero ($G = 0.04$, $p = 0.83$). Frequency of playing counting games was not related to pretest math performance.

Survey Question 4. The fourth question asked the parents, "How often does your child play games that require him or her to do simple sums?" The Goodman-Kruskal gamma correlation between frequency of playing simple sums games and pretest math performance was not significantly different than zero ($G = 0.18$, $p = 0.20$). Frequency of playing dice games was not related to pretest math performance.

It was of interest to determine whether the question on the survey regarding games that involve sums and the fact portion of the assessment might be correlated. To that end, a Goodman-Kruskal gamma was calculated for these specific data points. The Goodman-Kruskal gamma indicated that there was not a significant relationship between the survey question regarding games requiring simple sums and the fact portion of the pretest results, ($G = -0.13$, p = 0.50).

CHAPTER FIVE: DISCUSSION

A correlation between socioeconomic status and math achievement as measured by the Primary Math Assessment was not found. This differs from the results found in the research, which very consistently seems to find a correlation between socioeconomic status and math achievement (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). There are some factors that could explain this discrepancy. The first is that this study took place in the fall of the COVID pandemic. It is possible that all students' mathematics understanding differs from what is usually expected at this point due to the interruption of their normal lives. Another possibility is also related to COVID. There is evidence that students from higher income backgrounds are more likely to be enrolled in preschools of high quality (Nores & Barnett, 2014). This is important because these students often then go to kindergarten better prepared for mathematics instruction. During the COVID pandemic these preschool experiences were likely interrupted. This study might not have replicated the results of previous research in terms of socioeconomic status and early math achievement is the small number of participants. This study used maternal or primary caregiver's highest education level as a proxy for socioeconomic status because, due to COVID, all school meals were free for the 2020-2021 school year, eliminating the collection of Free and Reduced Lunch data. But the relationship between socioeconomic status and achievement in school is very complex with a variety of moderating and mediating variables (Reyes et al.,1988). Research has found the education level of parents to be a moderating variable in the relationship between socioeconomic status and mathematics achievement (Duncan & Magnuson, 2005). There is also research to suggest that the neighborhood has an impact on this relationship (Bradley & Corwyn, 2002; Sirin, 2005). The small town where this study was conducted might not be typical of other areas in the United States and maternal education level might not have the same relationship to student achievement that it does in other areas. The participants were self-selected. It is possible that there was something inherently different about the parents who returned the participation form and agreed to complete the survey and have their child participate in the study.

Research Question #1

The first research question, will change in performance on a mathematics assessment be influenced by playing a math game at home, was answered, in this study, in the negative. The results of this study did not find a significant difference between the students in the control group and the students in the interventions group's improvement in performance on the mathematics assessment. The study by Ramani and Siegler (2008) on which the current study was loosely based, utilized a research assistant to play the game with the students. This ensured that the students utilized the counting strategies that the authors had selected. In the current study this procedure was described in the instructions but there was no way to ensure that the parents employed this strategy.

Furthermore, the instructions also stated that the children could play with anyone, including siblings. It is unlikely that a sibling would have corrected the counting strategies of the kindergarten students. This reasoning is supported by the evidence presented by Sonnenschein et al., (2016) in which, in their first study, there was not a significant difference between the game groups and the control groups. The authors reported a significant increase in children's performance regardless of condition. But after performing focus groups they conducted study 2, in which the groups changed slightly. In this case they found that there was a significant relationship between number line estimation and performance for the children who were in the stickers with training group while the control group showed a decrease in accuracy from pre to post-test (Sonnenschein et al., 2016). In the stickers with training intervention group the students were trained in the counting strategy before they took the game home and then were given a sticker chart to incentivize them to play the game (Sonnenschein et al., 2016). It is possible that had the current study trained the students in the counting strategy before they took the game home the results might have been more encouraging.

Another reason that the intervention and control group might not have shown a difference in performance is that it is not clear exactly how many times the children played the game in the two-week period. The students and parents were instructed to play the game 20 times in the two-week period. This is the number of times that the game was played in the Ramani and Siegler (2008) study. All students were asked verbally about their frequency of playing and students who reported that they had not played or only played a few times were excluded. But, while the remaining students all reported that they had played at least 20 times, it was clear that there was a wide variation in the amount that they had actually played. Two students brought sticker charts back to school which were covered in stickers. They had not only filled the 20 slots but covered all remaining space with stickers. It is not clear if they actually played this many times or just liked using stickers. Six students forgot their sticker charts although they reported that they had played the game. Three children turned in sticker charts that were not completed but reported having played a lot. Table 5 displays the data related to adherence to the directions related to the sticker chart.

Table 5 Sticker Chart Completion Information

	Sticker charts filled in correctly	Sticker charts covered in stickers	Sticker charts partially filled but student report of playing the game "a lot"	No sticker chart but student report of playing the game 20 times
# of participants	17	2	3	6

It is possible that the students played the games at the beginning of the two-week period and then stopped playing once they reached 20 times. This problem was experienced in the Sonnenschein et al., (2016) study in which the authors reported that only 52% of the children returned logs specifying how long and with whom the children played the games. Furthermore, the frequency of play was spread out across the 2 weeks in the Ramani & Siegler (2008) study but this was not assured in the present study.

Research Question #2

The second research question, will students from low socioeconomic backgrounds improve their math scores more than students from high socioeconomic backgrounds after playing a math game at home, was also answered in the negative in this study. There was no significant difference in change from pre to post-test between the intervention group and the control group. Given that the meta-analysis conducted by Nelson and McMaster (2019) found that in the intervention studies they considered, the effect size for students identified as low SES was higher than average in interventions addressing early numeracy it was surprising that there was not a significant change found between these groups in this study. The small number of participants, the lack of uniformity in adherence to the frequency of game playing, and the lack of training in counting strategies are all likely contributors to the lack of support for the hypothesis.

Research Question #3

The third research question, is math performance related to the amount of game playing at home, was also answered in the negative. The survey results showed no correlation between overall responses to the questions regarding game playing at home and performance on the mathematics assessment. Again, this contradicts research surrounding this topic (Niklas et al., 2016; Ramani & Siegler, 2008). A possible reason for this discrepancy is that this study took place during the COVID pandemic. It is possible that all families are engaging in more games at home with their children. But this change has either not yet lasted long enough to improve children's math outcomes, or it is not representative of the home numeracy environment that previous studies have encountered. There could be something qualitatively different between the families that have always played games that utilize math concepts with their children, and families which began playing games during quarantine and this time of unprecedented time spent at home.

Limitations

There are a variety of limitations to this study. The first is the small sample size. Twenty-eight students reported having played the game and were both pre and post-tested. The participants were self-selected in that they had to sign and return the permission form to be eligible for the study. There were 57 students in the kindergarten, only 35 of those students returned the permission form. All kindergarten student families were called before the permission form was sent home. Many families expressed interest in participating yet did not turn in their forms. It is possible that, given that at this point in the school year the students were still only attending school twice a week, there were exceptional challenges in getting papers efficiently to and from school.

Another limitation is the participants. Not only were all the participants from the same school but the school in which this study was conducted is a dual immersion magnet school. So, students who attend have chosen to attend, it is not simply a neighborhood school. This is significant because it is possible that the population at the school is not representative of the general population. Doing this study throughout the school district or with an even larger population would have produced more generalizable results.

In general, the district where this study was conducted might not be representative of the general population. The district has a ski resort, and most of the industry is tourism. There are an unusual number of former professional athletes who live in the area. This specifically might have made the use of maternal education level to be an especially problematic measure of socioeconomic status given that many professional athletes do not finish college but are probably not very representative of families living in low socioeconomic status conditions.

While the families were instructed to play the game 20 times over the two-week period it was clear through interviews with the students that this was not done with fidelity. There were a wide range of experiences with the games reported. Two students returned their sticker charts covered in stickers, it was not clear if they had played that many times or had just enjoyed using the stickers. Three students returned sticker charts that were not complete but reported that they had played the game a lot. More structure to ensure better fidelity would have been helpful. Possibly, asking the families to play the game a certain number of times per day would have improved the fidelity of game playing. Or rather than a sticker chart a form that asked parents to sign each time the student played the game would have been useful.

In this study the participants were told that the game could be played with anyone. This was done to make the study as easy as possible for families to encourage them to actually play the game. But this also means that the students played with a wide variety of partners. Certainly, some played with their parents. This was likely a very different experience than the experience had by students who played with siblings. Asking that the students play with an adult might have been a better choice. Or, it might have been helpful to have the parents record who the child played with. Again, this was not done in an effort to make participation as easy as possible for the families involved. But the trade-off is that the game was played with a wide variety of partners.

It is also possible that some students played the game a lot at the beginning of the two-week period but then stopped playing when they reached 20 times. This would be a problem because it would effectively make the post-test a delayed post-test for a portion of the students. The result is that some students were immediately post-tested while there was a delay between intervention and post-test for other students. This problem could have also been addressed by asking the students to play a certain number of times per day rather than 20 times across the two-weeks. There was not a reliability check of the PMA data.

There was no training provided for parents or students in the counting strategy utilized by Ramani and Siegler (2008) and Sonnenschein et al. (2016). There was not training provided to the students due to time constraints. Without the time constraint the individual conducting the pre-test could have played the game with each student a few times and instructed him or her on the counting strategy. Or, it might have been useful to create a training video for parents that could have been shared virtually.

This study was done approximately a year into the COVID pandemic. It is likely that there were attributes to family life that during the time of the study that are not typical to the students' lives generally. For example, many students who would have attended pre-school during the spring of 2020 were at home with their families during this time. Their parents were likely trying to work from home and take care of their children. This is not a scenario that is nearly as common in normal times as it was during the COVID pandemic. This affects the generalizability of this study. Kindergarten students are unlikely to look like these particular kindergarten students at another point in time.

Another limitation related to the COVID pandemic and the timing of the study is that the pretest was done the same week that the students began coming to school four days a week. The students had been attending school twice a week and the previous school year had been entirely online for the final two and a half months of the school year. Clearly, this is not typical.

The measure that was chosen to measure the mathematics abilities of the students was a distal measure. The study might have been more effective had a more proximal measure been used. For example, it might have been more appropriate to have the students count to 15 or to demonstrate one to one correspondence counting to 15.

I chose to randomly select half of each income group for the control group and the intervention group. But there was a much higher proportion of native Spanish speaking students in the intervention group than in the control group, 53% compared to 31%. Clearly, this could have impacted the results.

The manner in which I measured socioeconomic status is in itself a limitation. Even in the definition provided by Duncan and Featherman (1972) parental education is only one of three of the main indicators of socioeconomic status. The use of Free and Reduced Lunch would have been a preferred manner to measure socioeconomic status, but due to the timing in the pandemic this information was not being collected.

Another limitation of this study is that I used an existing scale, which has reliability and validity data and I cut it in half. Because the measure was cut in half we cannot depend on its reliability or validity.

Implications

It would be informative to replicate this study with training of counting strategies and the game. In the Ramani and Siegler (2008) study a researcher played the game with the students and instructed them to move the number that they spun while saying the names of the numbers that they were moving over or onto. The Sonnenschein et al. (2016) study instructed the parents on the same count on procedure as used by Ramani and Siegler (2008). So, it would be useful to add this count on training to the current study.

To address the limitation of broad discrepancy in the amount that the students played the game, it would also be interesting to replicate this study in school, utilizing older students who are trained in the count on strategy to play with younger children.

This might be a way to retain the goal of keeping costs low but still providing more structure.

Another important implication of this study is that it was done during the COVID pandemic. As we move on from the pandemic it will be important to have data from this moment in time. We cannot guess at the long-term ramifications to the education of students during this time period but information gathered in the moment will be important as we dissect the impact.

Future research should attempt this at a larger scale. It is possible that the small sample size was not representative of the population. This research should also be attempted in a manner that creates more structure. Possibly, this study would have been more effective had the families been instructed to play a certain number of times a day or if there had been text or phone call reminders to continue to play.

Based on the literature reviewed there are many implications for teachers. Based on the research related to interventions teachers should focus their mathematics interventions on general numeracy skills (Mononen et al., 2014; Nelson & McMaster, 2019). The research regarding the home learning environment also has implications for teachers. Conversations with parents regarding fostering foundational skills could be useful, specifically, recommending the Bedtime Math app (Berkowitz et al., 2015) or the game Chutes and Ladders (Ramani & Siegler, 2008) could be helpful. The research regarding the utilization of games as an intervention could also be valuable to teachers. A positive approach might be to train kids at school on strategies and then send math games home to build foundational skills (Sonnenschein et al., 2016).

There are also important implications for schools based on the review of literature. Based on the research related to the predictive nature of early math skills it is important that school focus on early intervention. Resources supporting students in kindergarten and first grade in numeracy and number sense would be beneficial (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). A school focus on activities to build numeracy in the home is a reasonable response to the research related to the home learning environment (Galindo & Sonnenschein, 2015; Levine et al., 2010). Specifically, schools might consider hosting math nights or explore sibling “training” and activities. Given the research surrounding the utilization of games as an intervention (Baroody et al., 2009; Griffin, 2004; Ramani & Siegler, 2008; Whyte & Bull, 2008; Wilson et al., 2009), schools might consider math game nights or math clubs before or after school where students could play math games.

There are important implications of the research reviewed in this paper for parents. First, it is important for parents to understand that the home learning environment has an important impact on a student's readiness for kindergarten (Galindo & Sonnenschein, 2015; Levine et al., 2010). Simply incorporating numbers into everyday activities is a start (Levine et al., 2010). Parents who do not feel confident in their own math abilities could use games or the Bedtime Math app to support them in supporting their children (Berkowitz et al., 2015).

Finally, for the greater research community an implication of the literature review is that further research into interventions that can be done easily and cheaply in public schools is important. More research into using games as an intervention is also warranted- both at home and in the school setting.

Conclusion

There is a dearth of research that clearly describes the great import of mathematical understandings at an early age (Claessens & Engel, 2013; Jordan et al., 2009; Kiss et al., 2019; Watts et al., 2014). Mathematical understanding is not equally distributed among all children. Students from low-income homes are more likely to enter kindergarten deficient in mathematical understanding (Coley, 2002; Galindo & Sonnenschein, 2015; Jordan et al., 2006; Levine et al., 2010; Lloyd & Hertzman, 2009; Nores & Barnett, 2014). The home learning environment also plays a key role in students' development of mathematical understanding (Galindo & Sonnenschein, 2015; Levine et al., 2010). So, students will not enter kindergarten on equal footing when it comes to mathematical understanding and we can predict, to a certain extent, which students are more likely to struggle. Therefore, research to examine interventions to improve mathematics achievement for young children is vital. Specifically, it is vital that we consider interventions that might specifically help children from low socioeconomic backgrounds. The home learning environment is also an important piece of the puzzle and should be taken into consideration. Research has demonstrated that interventions targeting numeracy can be effective in improving students' math skills (Nelson & McMaster, 2019). Interventions that have had a home component have also been effective (Niklas et al., 2016; Starkey et al., 2004). There has also been research suggesting that game-based interventions could be an effective way to intervene and improve math outcomes for students (Baroody et al., 2009; Griffin, 2004; Ramani & Siegler, 2008; Whyte & Bull, 2008; Wilson et al., 2009). Of particular interest to this study was a study done by Ramani and Siegler (2008) which used a simple math game, played 20 times with a researcher, over the course of two-weeks to improve mathematics achievement.

Given this research, the purpose of this study was to provide kindergarteners with a simple math game or a reading game to be played at home, to investigate whether playing the math game at home might improve math scores for the students in that intervention group. But, upon conclusion of the study, it was found that this simple math game sent home for two-weeks did not improve the math outcomes for this group of children. This study also did not find a correlation between parent reports of frequency of playing games at home and math achievement as measured by the Primary Math Assessment. Previous studies have shown that math games can be an effective means by which to improve math achievement for young children (Ramani & Siegler, 2008; Sonnenschein et al., 2016). More research is warranted to determine how the promising research conducted by Niklas et al. (2016), Ramani and Siegler (2008), and Sonnenschein et al. (2016) might be further developed and explored. It is important that we find ways to intervene in developing mathematical understanding in a cost-efficient manner. It is imperative that we find ways to leverage what we know so that our knowledge can be utilized in public schools who do not have extensive resources.

I believe that this study provided an important addition to the current research in that it specifically set out to address the feasibility of interventions in our public school system. While it is vital that we learn which interventions are most effective in helping students to be successful in mathematics, we also need to be cognizant of the practicality of implementing those interventions in our schools. This study specifically set out to examine whether an intervention that was very practical for a public school could be effective.

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APPENDIX A

Games

Figure A1. **The intervention group math game.**

Figure A2. The control group English game.

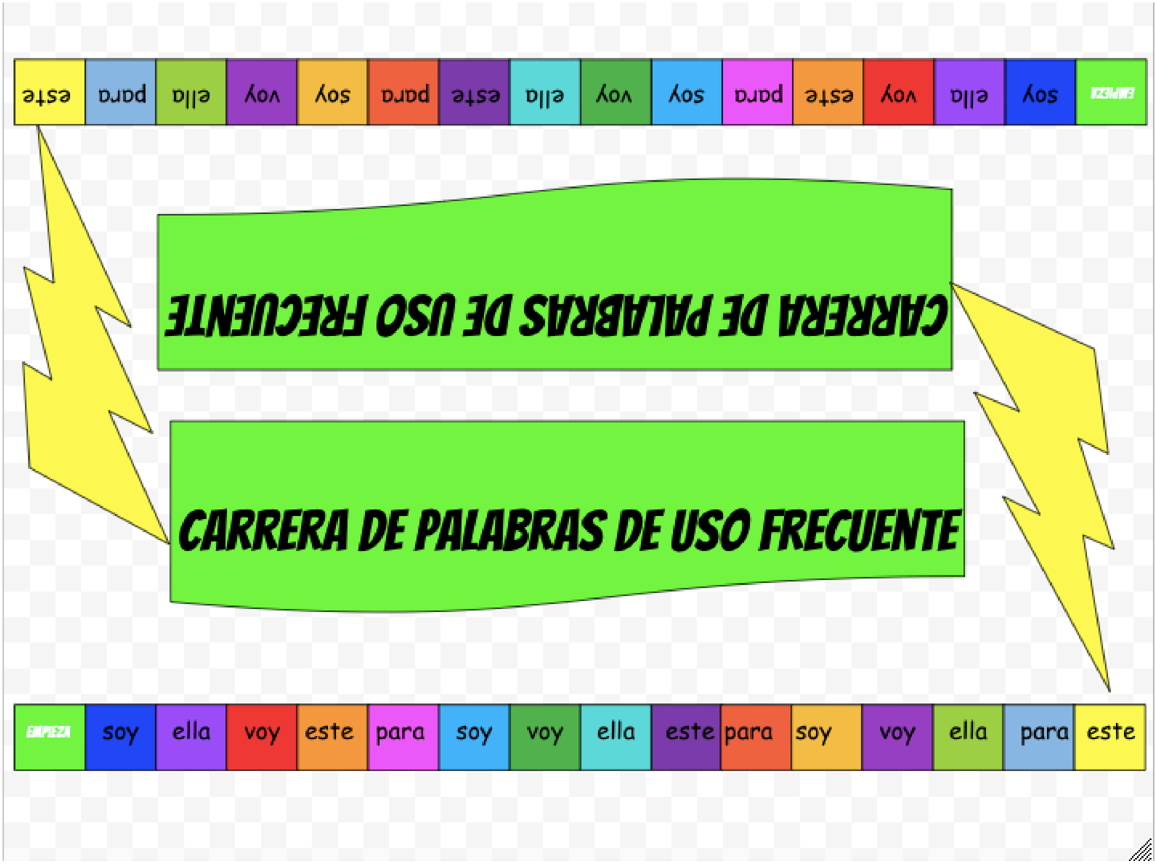

Figure A3. The control group Spanish game.