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Enhancing Numeracy in Young Children through a Parenting Intervention

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Abstract. *Children who enter a formal setting with a deficit in mathematics carry this deficit throughout their schooling (Galindo & Sonnenschein, 2015), and an early understanding of mathematical language is foundational for later mathematical understanding (Jamison, 2000). This study seeks to increase the mathematical language and interactions in the home prior to children entering kindergarten by providing parents with both mathematical activities and specific instructions related to each activity. Forty families with children ages three to five years old participated in a single group pretest-posttest study where hands-on mathematical activities were sent home each week for fifteen weeks. Parents completed an assessment of current home numeracy and expectations for the end of kindergarten, and children completed an assessment of mathematical understanding. Results indicate an increase in some areas of current home numeracy, parental expectations, and children's mathematical understanding over and above maturation. Findings, limitations, and implications for future research will be discussed.*

Keywords: *early childhood education, home numeracy, mathematics, parenting*

Parenting and the Enhancement of Numeracy in Young Children

The mathematics proficiency of students in the United States falls short in comparison to the performance of students worldwide (Organisation for Economic Co-operation Development [OECD], 2013), and students who enter school with mathematical deficits in kindergarten struggle with mathematics throughout their schooling career (Galindo & Sonnenschein, 2015). While the research on mathematical interventions with school-aged children is promising, little research has been conducted on the potential impacts of a home numeracy intervention prior to children entering kindergarten.

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Parenting and Early Mathematical Learning

Vygotsky's theory of sociocultural learning focuses on the spaces between lower level learning and higher level learning, or the zone of proximal development (ZPD) (Abtahi, 2018). Wass and Golding (2014) define the ZPD as the area where children cannot do a task on their own yet, but can do it with assistance from an adult. It is important to note the social component of the ZPD, where learning happens through interactions with others. Children absorb their knowledge through interacting with those in their environment and learning concepts in all content areas through language, including mathematics (Pupura & Reid, 2016; Samara & Clements, 2009).

Mathematical concepts begin developing in infancy and toddlerhood with symbolic representation and spatial awareness (Geist, 2001), which develops into an understanding of both the symbolic nature of numbers and reasoning skills (Aubrey & Godfrey, 2003). Parents and caregivers of young children are an essential component to integrating mathematics into children's daily lives through using mathematical language and unstructured, play-based activities (Melhuish, 2010).

In the content area of mathematics, a grasp of mathematical language is essential for completing mathematical operations and enhancing conceptual understanding of mathematical concepts (Jamison, 2000; Samara & Clements, 2009; Lee & Kotsopoulos, 2016). Children typically acquire mathematical concepts through three mechanisms – linguistic, spatial reasoning, and quantitative – however, in young children, the linguistic mechanism or the language in the context of mathematics predicts early numeracy above and beyond the other two (LeFerve et al., 2010). Given that language is acquired early and through the child's environmental context, the language presented in the home numeracy environment is fundamental for mathematical understanding.

Home Numeracy in the Preschool Years

Research to date has focused on relationships within the home numeracy environment, group differences, and interventions in the early school years. Napoli and Purpura (2018) explored the relationship between the home literacy and numeracy environment in the preschool years and determined that the home numeracy environment impacted children's numerical and definitional vocabulary, linking the home numeracy environment to language development. Furthermore, Niklas, Cohrssan, and Tayler (2015) determined that educating parents of preschoolers on the home numeracy environment and early mathematical concepts can improve children's mathematical outcomes in the preschool years. Skwarchuk (2009) found differences in the amount that mothers discussed numerical information with boys and girls at age 22 months; before age two, mothers are significantly more likely to use numerical information in conversation with their sons than with their daughters. Findings from these studies demonstrate the utmost importance of early numeracy and its relationship to parenting and the overall home numeracy environment.

Parent-child interactions in the home numeracy environment can take on both a formal and an informal context (Skwarchuk, Sowinski, & LeFerve, 2014). Skwarchuk et al. (2014) define formal activities "as shared experiences in which parents directly and intentionally teach their children about numbers, quantity, or arithmetic to enhance numeracy knowledge" and informal activities as "shared activities for which teaching about numbers, quantity, or arithmetic is not the purpose of the activity but may occur incidentally (e.g., playing number board games; measurement activities required in cooking, carpentry, or crafts; quantity comparisons; spatial processing)" (p. 65). Each contributes uniquely to the child's mathematical learning, with formal activities predicting children's knowledge of symbolic numerical systems and informal activities predicting children's non-symbolic arithmetic. Lee and Kotsopoulos (2016) discuss the concept of purposeful mathematics talk, where parents intentionally discuss mathematics concepts in the context of play related to mathematics as well as in daily activities and routines. Both studies highlight the necessity of parent-child interaction in the context of children's mathematical learning.

Contextual factors also influence the home numeracy environment. Galindo and Sonnenschein (2015) demonstrated a deficit in early numeracy for Kindergarten children from low SES families at the beginning of school. Niklas and Schneider (2014) examined the impact of the home numeracy environment on children in the early schooling years, and they found that the home numeracy environment influenced children's understanding of numerical concepts. Interestingly, children whose family had a history of dyscalculia had a less favorable home numeracy environment than children whose family had no history of mathematical disability. Pupura and Reid (2016) also explore group differences in the home numeracy environment, and found that parent's with less than a college education acquired less mathematical language than their peers. However, 93% of Americans experience some level of math anxiety at some point in their lives (Blazer, 2011), and 17% report high levels of math anxiety (Ashcraft & Moore, 2009). Parents who have higher levels of math anxiety are less likely to discuss foundational mathematical language and concepts with their young children.

Given the dramatic shift to social distancing and learning at home, parents have been called upon to continue their children's education in the midst of crisis. Many are relying on outside resources, such as online activities and apps, to fulfill this role (Kehoe, 2020). While this may be appropriate for older children, younger children need hands on activities and playful interactions with adults to enhance their cognitive and language development (Goldstein, 2012). By providing parents with an intensive mathematical intervention, including hands-on activities and specific instructions related to each activity, this study seeks to increase the mathematical interactions in the home and the language in the context of mathematics.

Current Study

The purpose of the current study is to examine the impact of parent's mathematical expectations and the current home numeracy environment on children's mathematical understanding. Specifically, the following research questions will be addressed:

1. How are parents currently supporting children's early numeracy in the home, and did this change significantly throughout the intervention?
2. What are the changes in parents' expectations for their child's mathematical understanding over the course of the intervention?
3. In what ways does parental use of mathematical activities impact children's mathematical understanding?

Methods

Participants

Forty families with children ages 3-5 at the onset of the study were recruited from two preschools in Texas: a rural university laboratory school ($n = 13$) and a suburban faith-based preschool ($n = 31$). Of the 44 families at the onset of the study, 40 completed all 15 weeks of intervention and all assessments. Attrition was due either to families moving ($n = 2$) or dropping out due to time constraints ($n = 2$). Twenty-three boys and seventeen girls completed the study, and the average age of the child at the start of the study was $M = 4.08$ ($SD = 0.64$). The majority of the sample was comprised of families that were White, non-Hispanic ($n = 31$); five families identified as African American, three as Hispanic, and one child was identified as biracial.

Procedures

Data were collected in three waves; the first pilot study took place over 18 weeks at a rural university laboratory school, and the second and third replication studies were implemented over two separate 18 week periods at a suburban faith-based preschool. Prior to the start of each wave of data collection, informed consent was obtained from all parents of the children participating in the study. Child assent was not obtained because children were under the age of seven. This study employed a single group pretest-posttest design and occurred in three phases. Phase 1 – Pre-Assessments included a home numeracy survey and an assessment of the child's numeracy skills. During Phase 2 – Intervention, parents received early numeracy activities each week through their child's school with instructions for the activity for 15 weeks. Parents completed weekly surveys about each activity. Phase 3 – Post-Assessments consisted of another home numeracy survey and assessment of the child's numeracy skills.

Activities. Activities for this study were designed by a researcher with expertise in early childhood numeracy, and they were balanced across National Council of Teachers

of Mathematics (NCTM, 2000) content areas – numbers and operations, data analysis, geometry, and classification/comparison and patterning (pre-algebra skills). These activities were chosen because they encourage parent-child interaction and the use of mathematical language as well as cover a variety of content areas. Parents were given the reasoning behind each activity's concepts as well as instructions on how to complete the activity as intended. Furthermore, parents were provided with an easier version if the activity proved too difficult, and a challenge version if the activity was too easy. Additionally, an 'around the house' section provided ideas for how parents could continue to expand on these concepts even after the materials were returned for the intervention. The activities are specifically designed to embody purposeful play in the context of mathematics (Lee & Kotsopoulos, 2016). See Table 1 for a list of all activities and NCTM (2000) content areas.

Table 1.

Fifteen weekly intervention activities descriptions and their NCTM (2000) content areas.

Activity	Description	Content Area
Button Graphing	Use assorted colors and shapes of buttons to complete blank graph; count and write numbers of buttons in each group	• Numbers and Operations • Classification/Comparison • Data Analysis • Geometry
Spill the Beans	Put red side/white side beans in cup and spill out some; have child count number spilled, which side has more, estimate number left in cup	• Number and Operations • Classification/Comparison
Activity	**Description**	**Content Area**
Let's Move	Roll single die, draw a movement card, and perform the number of movements; add second dice and add numbers for challenge	• Number and Operations
Transportation Patterns	Sort by different type of vehicle and/or color; use existing patterns to complete pattern with vehicles; create own pattern	• Classification/Comparison • Patterning
Nursery Rhyme Addition	Follow scripted nursery rhyme and use cotton balls to count, add, and subtract	• Number and Operations
Teddy Bear Stories	Follow scripted story to count bears and sort based on color and size	• Number and Operations • Classification/Comparison
Measure It	Use snap cubes to measure height and length of objects; count number of cubes used for each object; sort objects based on length or height	• Number and Operations • Classification/Comparison • Data Analysis

Where's the Button?	Using buttons and grid, determine what comes next based on button shape and color; use buttons to create patterns in grid	• Patterning • Geometry
Number Towers	Identify numbers and recreate using snap cubes; determine which has more or less in the tower	• Number and Operations • Classification/Comparison
Sharing Hot Dogs	Use play dough to make 'hot dogs' and have children cut into various lengths; discuss fraction concepts, compare more and less	• Number and Operations • Classification/Comparison
Traffic Jam	Have children line up vehicles on paper and count number of vehicles; create patterns with vehicles; compare more or less in each line	• Number and Operations • Classification/Comparison • Patterning
Clothespin Addition	Use craft sticks and clothespin counters to create and solve addition problems	• Number and Operations
Bears in the Bed	Draw number card and place that number of bears on the bed; draw two cards and add them together; determine if there are more, less, or the same number of bears; chart who has more or less more often	• Number and Operations • Classification/Comparison • Data Analysis
Activity	**Description**	**Content Area**
Boiling Beans	Start with 20 beans and spill some out; add, subtract, and estimate number of beans inside and outside of a pot	• Number and Operations
Shapes Builder	Choose a two-dimensional or three-dimensional shape card and recreate the shape with playdough; describe and name each shape	• Geometry

For example, the activity "Let's Move" came with movement cards, dice, and a set of instructions that read:

"Children learn number recognition the more they are exposed to numbers in print. Show the children pictures of the action cards or create your own actions. Ask your child to:

- roll one die and pull an action card
- do the action as many times as the number on the die
- pass the die to the next player to do the same

Challenge: Have your child roll 2 dice and add together to determine the number of times to do the action. **Simplify**: Count with your child as he does the actions, ensuring that one action occurs for each number. **Around the house**: encourage your child to

find a specific number in sales ad, flyer or newspaper. In the car, play "I Spy" with license plates on cars passing or signs on the road, naming a number for the child to look for. Send your child on a number hunt around the house and write all the numbers they find."

Measures

Home Numeracy Questionnaire (Kleemans, Peeters, Segers, & Verhoeven, 2012) – This Likert-type rating scale covers two areas of parenting and mathematics. First, the parents rate their expectations of their children's mathematical skills by the end of kindergarten on a 4 point scale (6 items, Chronbach's alpha = 0.92). Second, parents rate the frequency of certain activities they engage in with their child on a 5-point scale (5 items, Chronbach's alpha = 0.79).

Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003) – The TEMA-3 assesses mathematical knowledge for children ages 3 years to 8 years, 11 months. It contains items that measure early numeracy learned in both a formal and informal setting. Two parallel forms have 72 items each, and an age-referenced standard composite score will be computed for each participant. "Test-retest (r = 82), alternate reliability (r = 97), and internal consistency (α = .94) are excellent and criterion validity (range, .54 to .91) is adequate" (Codding, George, Ferreira, Chan-Iannetta, & Volpe, 2011, p. 88). The TEMA-3 is scored based on the child's age in years and months, with norms changing every three months to account for maturation.

Parent Survey – Researchers designed a short survey for parents to answer about the activities that are sent home weekly. This survey measures the frequency that the family participated in the activity, the amount of minutes spent with the activity over the course of the week, and whether or not the parents and children enjoyed the activity with an open-ended section for comments.

Data Analysis Plan

Given the single group pretest/post-test nature of the study, paired sample *t*-tests will be used to determine changes in current home numeracy practices, parental expectations, and children's mathematical understanding. Cohen's *d* will be used for calculating effect sizes for significant results, with 0.2 considered a small effect, 0.5 considered a moderate effect, and 0.8 considered a large effect (Cohen, 1998).

Results

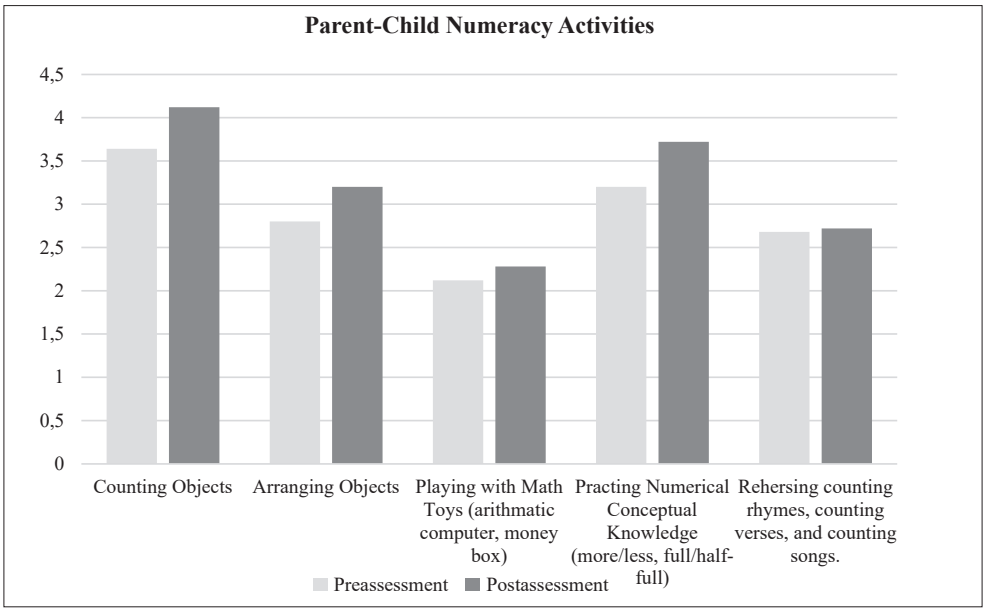
Results indicate a significant increase in two categories of the current home numeracy environment, two categories of parental expectations for children's mastery at the end of kindergarten, and in children's mathematical understanding over the course of the intervention.

Current Home Numeracy Environment

Paired sample *t*-test indicate a significant increase in the home numeracy environment in two categories: counting objects ($t = 2.49$. $p < .05$, $d = 0.50$) and practicing numerical content knowledge ($t = 2.18$, $p < .05$, $d = 0.44$) (See Figure 1), indicating a moderate impact of the intervention process on current parental math practices at home. A handful of parents commented on "Playing with Math Toys" that they do not have these particular toys at home.

Figure 1

Change in numerical activities that parents are currently engaging with at home.

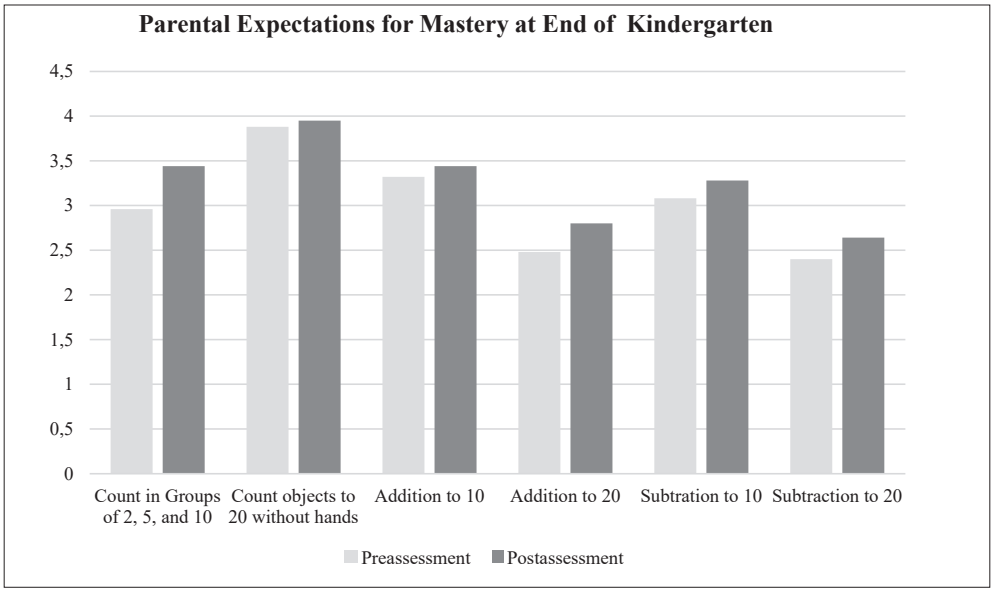


Parental Expectations

Paired sample *t*-test indicate a significant increase in parental expectations in two categories: counting in groups of 2, 5, and 10 ($t = 2.14$. $p < .05$, $d = 0.43$) and addition to 20 ($t = 2.14$, $p < .05$, $d = 0.43$). The intervention had a small to moderate impact on parent's expectations on what they expect their children to master by the end of kindergarten. Moreover, addition to 10, subtraction to 10, and subtraction to 20 were not significant, though mean increases were shown for these categories as well (See Figure 2).

Figure 2

Change in parental expectations for children's master of mathematical skills by the end of kindergarten.



Children's Mathematical Understanding

Children's mathematical understanding was enhance over the course of the intervention above and beyond a normal age increase. Paired sample *t*-test indicate a significant improvement in percentile rank ($t_{(39)} = 3.13, p < .01, d = 0.49$). The intervention itself has a moderate significant effect on children's mathematical understanding even when accounting for maturation.

Discussion

This study demonstrates the ability to impact the home numeracy environment and children's mathematical understanding through a strategic, activity-based mathematical intervention. Both current home numeracy practices and parental expectations for children at the end of kindergarten increased over the course of the study, depicting a change in the parents' overall framework around mathematics. By increasing both the numeracy practices in the home as well as what the parents expect of their children in kindergarten, the home numeracy environment is enriched.

Furthermore, children's mathematical understanding increased above and beyond what would be expected due to maturation based on the measure used. The TEMA-3 uses three-month intervals for their norm scores, thus the children were scored against age-appropriate criteria despite their increase in age over the 15-week intervention (Ginsburg & Baroody, 2003). The increase over and above natural maturation can be

attributed to the both direct positive influence of increasing the interactions specifically related to numeracy in their home and the indirect use of mathematics language (LeFerve et al., 2010). Theoretically, children who have a foundational understanding of mathematical concepts when they enter school should fare well in mathematics throughout their schooling career (Blevins-Knabe & Austin, 2016).

Limitations and Implications for Future Research

One limitation of the current study is the population, which is fairly small and homogeneous given that the children attended preschool and were from predominately white families. Future research should explore this intervention with a more diverse population, including children from various ethnic and racial backgrounds, English language learners, and children who are at home with their parents full-time. Another limitation is the lack of the control group; a more robustly designed study with a control or comparison group would allow for a stronger interpretation of the results and an increase in the reliability of the study. Additionally, future research could compare the use of a technological intervention comparable to a hands-on intervention to determine if the impact is any intervention or specifically related to the activity-based approach.

Conclusion

Based on the findings in this study, introducing numerical concepts in the home environment and encouraging parent/child interaction about numeracy positively impacts parental perceptions of early numeracy. Early mathematical interventions have the potential to positively influence children's mathematical learning. As this is a largely untapped field, the data from this study will demonstrate the importance of introducing numerical concepts early and often to young children through the home numeracy environment. This information will inform the field of early childhood education as well as pave the way for larger and more diverse studies evaluating the impact of parenting and the home environment on early numeracy.

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Summary

Children who enter a formal setting with a deficit in mathematics carry this deficit throughout their schooling (Galindo & Sonnenschein, 2015), and an early understanding of mathematical language is foundational for later mathematical understanding (Jamison, 2000).

The **purpose** of the current study is to examine the impact of parent's mathematical expectations and the current home numeracy environment on children's mathematical understanding.

Specifically, the following research questions were addressed:

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