2015

Teacher Mathematics Language: Its Use in the Early Childhood Classroom and Relationship with Young Children's Learning

Emma Whitman
Loyola University Chicago

Recommended Citation
https://ecommons.luc.edu/luc_diss/1498

This Dissertation is brought to you for free and open access by the Theses and Dissertations at Loyola eCommons. It has been accepted for inclusion in Dissertations by an authorized administrator of Loyola eCommons. For more information, please contact ecommons@luc.edu.
Creative Commons License
This work is licensed under a Creative Commons Attribution-Noncommercial-No Derivative Works 3.0 License.
Copyright © 2015 Emma Whitman
LOYOLA UNIVERSITY CHICAGO

TEACHER MATHEMATICS LANGUAGE:
ITS USE IN THE EARLY CHILDHOOD CLASSROOM
AND RELATIONSHIP WITH YOUNG CHILDREN’S LEARNING

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE GRADUATE SCHOOL
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

PROGRAM IN CHILD DEVELOPMENT

BY
EMMA WHITMAN
CHICAGO, IL
MAY 2015
ACKNOWLEDGEMENTS

First to my committee, Jie-Qi Chen, you have always challenged me to be a better educator, researcher and person. Thank you for your attention to detail, process and reasoning. I thank you the most for your continued support of me and of this work. To Gillian McNamee, thank you for always pushing me to find the story; for teaching me to find the moment within the big picture. Your questions, reflections, and vision have taught me so much. To Jennifer McCray, whose work inspires my own. Thank you for leading me towards early mathematics education, and for teaching me how to become a researcher. To my husband, thank you for making me laugh and for your never-ending support. To my mother, you are an inspiration in all you do. You are my foundation, my mentor, and my friend.

Finally, this work is dedicated to my father, the boundless philosopher. Thank you for teaching me to always ask questions and for never doubting that I could find the answers on my own.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................... iii

LIST OF TABLES ....................................................................................................................... vii

LIST OF FIGURES .................................................................................................................... ix

LIST OF ABBREVIATIONS ........................................................................................................ x

ABSTRACT ............................................................................................................................... xi

CHAPTER I: INTRODUCTION ................................................................................................... 1
  The Importance of Early Mathematics Education ............................................................... 3
  Early Math Teaching in the Classroom ................................................................................. 5
  Developing Children’s Mathematics Concept Knowledge through the Use of
    Teachers’ Mathematics Language .................................................................................... 8

CHAPTER II: LITERATURE REVIEW ..................................................................................... 13
  Theoretical Framework: Language as a Tool in the Learning Process ............................... 16
  Social Interactions ................................................................................................................ 16
  Language as a Tool .............................................................................................................. 18
  Summary ............................................................................................................................... 21
  The Power of Words: Research on the Connection between Language and
    Children’s Learning ............................................................................................................ 24
  The Frequency of Language Input as it Relates to Child Outcomes ................................. 25
  Instructional Settings, Teachers’ Language, and Child Outcomes ................................. 27
    Definitions of instructional settings .................................................................................. 28
    Empirical research ............................................................................................................ 29
  Teacher Language as a Tool for Cognitive Change ............................................................ 34
    Quality interactions .......................................................................................................... 34
    Categorizing teacher talk .................................................................................................. 36
  Summary ............................................................................................................................... 42
  Empirical Studies on Teachers’ Mathematics Language in the Preschool Classroom .. 43
  Rationale for the Present Study............................................................................................ 49
  Types of Math Content Emphasized in Teachers’ Language ............................................. 51
  Instructional Settings and their Mediating Effect on the Relationship between
    Teacher Language and Child Outcomes .......................................................................... 53
  Level of Cognitive Demand in Teachers’ Mathematics Talk .......................................... 55

CHAPTER III: METHODS ...................................................................................................... 58
  Study Design and Research Questions .............................................................................. 58
  Participants ............................................................................................................................ 59
  Teachers ............................................................................................................................... 59
  Children ............................................................................................................................... 61
  IRB ....................................................................................................................................... 62
CHAPTER IV: RESULTS .......................................................................................................................... 73
Teachers’ Mathematics Language: Math Content .............................................................................. 73
Types of Content Strands Emphasized in Teachers’ Math Language .............................................. 74
Relationship between Frequency and Type of Teachers’ Mathematics Language, and Child Outcomes in Mathematics .............................................................................................................. 77
Teachers’ Mathematics Language: Instructional Settings ................................................................ 80
Frequency and Rate of Teachers’ Math Language in Instructional Settings ..................................... 81
Teachers’ Mathematics Language in Each Setting and its Relationship to Child Math Outcomes .. 84
Additional Analyses ......................................................................................................................... 87
Teachers’ Mathematics Language: Level of Cognitive Demand ..................................................... 88
Level of Cognitive Demand in Teachers’ Mathematics Talk: Frequency and Relationship to Child Math Outcomes ..................................................................................................................... 88
Level of Cognitive Demand in Teachers’ Math Talk: Relationship to Child Math Outcomes .......... 91

CHAPTER V: DISCUSSION .................................................................................................................. 94
Teachers’ Math Language: Math Content ......................................................................................... 97
Teachers’ Math Language: Instructional Settings ............................................................................ 103
Descriptive Statistics on Teachers’ Mathematics Language in Three Instructional Settings .......... 104
Teachers’ Mathematics Language in Each Setting and its Relationship to Child Math Outcomes .. 105
Small group ........................................................................................................................................ 107
Free play .......................................................................................................................................... 108
Large group ......................................................................................................................................... 112
Summary: Instructional Settings ........................................................................................................ 114
Teachers’ Math Language: Level of Cognitive Demand ................................................................. 115
Four Content Strands ......................................................................................................................... 116
Combined Number and Operations Language .................................................................................. 117
Relationship to Child Math Outcomes ............................................................................................. 118
Limitations and Implications ............................................................................................................. 124
Limitations .......................................................................................................................................... 124
Implications ......................................................................................................................................... 128
LIST OF TABLES

Table 1. Examples of Levels of Cognitively Challenging Language during Small-Group Activity (Durden & Dangel, 2008) ................................................................. 42

Table 2. Language of Math Coding Categories and Examples (Rudd et al., 2008) ........ 47

Table 3. Types of Cognitive Demand in Preschool Teachers’ Mathematics Language ... 66

Table 4. Frequency and Percentage Comparisons of Teacher Math Talk across Content Strands (including two outliers) ................................................................. 75

Table 5. Mean and Standard Deviation of the Frequency of Teachers’ Mathematics Language across Content Strands ................................................................. 77

Table 6. Results of 2-Level HLM Model to Predict Children’s Gains on CMA Teachers’ Mathematics Language, Two Groups (“number and operations language” and “other mathematics language”) as Predictors ........................................ 80

Table 7. Frequency and Rate of Teacher Math Talk (number and operations language) across Instructional Settings ............................................................................ 82

Table 8. Means and Standard Deviations of the Frequency and Rate of Teachers’ Mathematics Language across Instructional Settings ................................. 83

Table 9. Results of 2-Level HLM Model to Predict Children’s Gains on CMA, Teachers’ Mathematics Language in Each Setting as a Predictor ............................. 85

Table 10. Results of 2-Level HLM Model to Predict Children’s Gains on CMA, Teachers’ Rate (intensity) of Mathematics Language in Each Setting as a Predictor ... 86

Table 11. Levels of Cognitive Demand in Teacher Math Talk: Frequency and Percentage across Content Strand ..................................................................................... 88

Table 12. Levels of Cognitive Demand in Teacher Math Talk: Frequency and Percentage in Two Categories ....................................................................................... 90

Table 13. Results of 2-Level HLM Model to Predict Children’s Gains on CMA, Teachers’ High, Medium and Low Level Number and Operations Language as a Predictor ................................................................. 92
Table 14. Results of 2-Level Weighted HLM Model to Predict Children’s Gains on CMA, Teachers’ High/Medium (combined) and Low Level Number and Operations Language as a Predictor ................................................................. 93
LIST OF FIGURES

Figure 1. Vygotsky’s Representation of the Teacher-Child Relationship ............................... 22

Figure 2. Representation of Current Research on Teachers’ Mathematics Language in the Preschool Classroom .................................................................................................................. 23

Figure 3. Three Elements of Teachers’ Mathematics Talk to Be Examined ............................. 51

Figure 4. Analysis of Outliers in Geometry Strand .................................................................. 76

Figure 5. Teachers’ Language Use: Math Content Strands .................................................... 77

Figure 6. Frequency of Teachers’ Mathematics Language in Three Instructional Settings ................................................................................................................................. 84

Figure 7. Rate of Mathematics Language in Three Instructional Settings
(frequency of number and operations utterances divided by time spent in each setting) ................................................................................................................................. 84

Figure 8. Levels of Cognitive Demand in Teacher Math Talk: Frequency across Content Strand ................................................................................................................................. 89

Figure 9. High, Medium, and Low Level Teacher Language (number and operations strands) ................................................................................................................................. 90

Figure 10. Representation of Current Research on Teachers’ Mathematics Language in the Preschool Classroom ........................................................................................................... 97

Figure 11. Relationship between Teachers’ Mathematics Language and Children’s Mathematics Outcomes .................................................................................................................... 103

Figure 12. Mediating Effects of the Small Group Setting on the Relationship between Teachers’ Mathematics Language and Child Outcomes in Mathematics .... 115

Figure 13. New Representation of Research on Teachers’ Mathematics Language in the Preschool Classroom ................................................................................................................ 133
LIST OF ABBREVIATIONS

NAEYC: National Association for the Education of Young Children
NCTM: National Council of Teachers of Mathematics
NCEDL: National Center for Early Development and Learning
ECLS-K: Early Childhood Longitudinal Study-Kindergarten
OCM: Observational Coding Matrix
EMC: Early Mathematics Collaborative
TMLM: Teacher’s Mathematics Language Measure
SPSS: Software package used for statistical analysis
MCDLM: Measure of Cognitive Demand in Mathematics Language
CMA: Child Mathematics Assessment
HLM: Hierarchical Linear Modeling
IQR: Interquartile Range
ABSTRACT

Early mathematics instruction has been linked to children’s later outcomes in both literacy and mathematics. One important component of this instruction, teachers’ mathematics language in the early childhood classroom, has been connected to children’s mathematical gains. However, this work is lacking in both scope and depth. The objective of this study was to provide a review of the use of math language by early childhood teachers and address the issues neglected in the current literature. The study looks at: the type of content that teachers’ mathematics language emphasizes, the mediating effects of settings on the mathematics language that is used, and the contributions of cognitive demand in teachers’ mathematics talk on children’s learning. The sample included 27 preschool teachers and 227 students. Archival data (gathered in 2008-2010) from the Early Mathematics Collaborative at Erikson Institute was used. This study employed three measures: Teachers’ Mathematics Language Measure (TMLM), Measure of Cognitive Demand in Mathematics Language (MCDML) and the Child Mathematics Assessment (CMA). The results show that preschool teachers’ number and operations language is predictive of children’s outcomes in mathematics. The small group setting was also validated as an important setting for early math instruction. Additionally, the study illustrates an important connection between the cognitive demand teachers’ language places on the child and children’s development of mathematical concepts. This study provides significant information regarding the conceptualization of teachers’ mathematics language and offers suggestions for professional development. Results show
that teachers’ can use mathematics language more intentionally and effectively in the early childhood classroom.
CHAPTER I

INTRODUCTION

The early learning standards movement in the late 1990’s has altered the practice of early childhood education across the nation in significant ways (Bowman, Donovan, Burns, 2001; Scott-Little, Lesko, Martella, & Milburn, 2007). One of the most noticeable changes is the focus on content knowledge in young children’s learning. The field of early childhood education has traditionally given relatively little attention to the issue of content knowledge. This tradition is based in part on the concern that overemphasis on content may narrow the focus of early education to promoting mastery of factual knowledge and discrete skills that are developmentally inappropriate to young children (Bredekamp, 1987; Elkind, 1987). In response to the standards and accountability movement, early childhood educators have begun to examine the role of content knowledge in the delivery of quality instruction and effective teaching. Many now recognize that content teaching and developmentally appropriate practice are not incompatible. Early learning experiences can help young children build strong foundations for school achievement and future success (NAEYC, 2009; National Research Council, 2009).

The first content area that received a wealth of attention from early childhood educators was literacy. As a society, we are keenly aware of the importance of helping children learn to read and write from an early age. Over the past two decades, millions of dollars and thousands of projects have been devoted to improving young children’s early
literacy skills. So successful have been the efforts of the early literacy community that “Today… early childhood literacy is regarded as the single best investment for enabling children to develop skills that will likely benefit them for lifetime” (Dickinson & Neuman, 2006, p. 1). In contrast, early math learning became a topic of discussion among early childhood educators only recently (Clements & Sarama, 2004). The development of early mathematics standards is gaining momentum (Illinois Board of Education, 2013). Although an increasing number of people recognize that early mathematics understanding contributes significantly to school achievement in later years (Copley, 2010; Duncan et al., 2007; National Research Council, 2009), the field of early education is still in the early stages of in knowing what constitutes high quality early mathematics education and what are the effective ways to help young learners gain foundational knowledge in mathematics.

The present study is an attempt to address some of the questions pondered by early math researchers and educators. It focuses on one aspect of quality early math instructional practice: namely, teachers’ use of mathematics-related language. To contextualize the study, this introduction section will first delineate why early math is an important topic to study. Special attention will be given to the emerging research on young children’s mathematical abilities and the relationship between early mathematical learning and later school achievement. The next section will describe what the field of early math practice looks like in the classroom, focusing on the preparedness of early childhood teachers and their instructional practices. The discussion then moves to how teachers can help young children develop strong mathematical skills. Among the many strategies that will be considered, one is highlighted: teachers’ use of mathematics
language. How this study is particularly relevant to me, as an educator, administrator, and scholar will also be noted. The introduction concludes with the purpose of the present study: To improve math content teaching and young children’s math learning by encouraging teachers to use mathematics language more intentionally and effectively in the classroom. A major goal of this work is to give meaning to what is happening with teachers’ mathematics language in the preschool classroom and to expand the field’s conception of what mathematics language is and what it can do to impact children’s learning.

The Importance of Early Mathematics Education

Early mathematics education refers to teaching that is designed to help young children develop math concepts during their preschool and kindergarten years (Ginsburg, Lee, & Boyd, 2008). Two major research developments have led to growing appreciation of the importance of early math education. First, research has shown that young children are able to understand more complex mathematical concepts than was previously thought (Clements & Sarama, 2007; Wynn, 1992). Second, research has suggested that performance in early mathematics significantly impacts later school achievement and success (Duncan et al., 2007; Jordan, Kaplan, Locuniak, & Ramineni, 2007). Both developments, described below, have led to a “call to action” from researchers and policy makers urging more attention paid to early mathematics education (see summary in National Research Council, 2009).

Traditionally, mathematics education has not been considered developmentally appropriate for young children. Math is abstract while young children are deemed to be concrete thinkers; cognitive developmental work done in the mid-twentieth century has
been used to suggest that young children’s mathematical ideas develop on their own timetable, independent of environmental factors like teaching (Piaget, 1929, 1969). Over the past two decades, however, a growing body of literature has indicated that many mathematical competencies, such as sensitivity to set size, pattern, and quantity, are present very early in life (see National Research Council for a summary report, 2009). Young children have more mathematical knowledge, such as an understanding of number and spatial sense, than we previously believed. In fact, most children enter school with a wealth of knowledge and cognitive skills that provides a strong foundation for mathematical learning (Clements & Sarama, 2009; Ginsburg, Lee, & Boyd, 2008).

There is also new evidence that achievement in early mathematics has an impact on later school success (Duncan et al., 2007; Jordan et al., 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Two studies illustrate this connection. In a meta-analysis of six longitudinal studies, Duncan and colleagues (2007) found strong correlations between mathematics skills in preschool and later achievement in both literacy and mathematics in grades three and five. Further, early mathematics performance was found to have the strongest predictive power, stronger than early reading ability, for success in later schooling (Duncan et al., 2007). A second study, by Jordan and colleagues (2009), found that number sense during the kindergarten year was predictive of the rate of growth in mathematics learning between first and third grade. Again, the early mathematical learning was reported by the authors to connect to overall competence in mathematics during later school years (Jordan et al., 2009).

These two areas of recent research are important contributions to the field of early math education (Clements & Sarama, 2009; Duncan et al., 2007; Ginsburg, Lee & Boyd,
The first expands our knowledge of young children’s capacity to learn mathematics and challenges early childhood educators to find ways to support and nurture such capacity in developmentally appropriate ways (National Research Council, 2009). The second area of research illustrates the importance of early mathematics education as it appears to provide children with a distinct educational advantage in later years (Duncan et al., 2007; Jordan et al., 2007). These research findings indicate that early childhood educators need to pay greater attention to early math education and ensure quality early math teaching take place in the classroom (Barnett, 2008; Clements, Sarama, & DiBase, 2004; NAEYC & NCTM, 2009, 2010; National Research Council, 2009).

**Early Math Teaching in the Classroom**

To provide young children with high quality mathematics learning experiences, the field needs to be prepared on at least two fronts. One, the field needs to understand what constitutes early math education and what quality early math teaching looks like. In addition, quality math education depends on the availability of mathematically competent teachers. After all, young children cannot become mathematically skilled without appropriate instruction and guidance from knowledgeable adults. Unfortunately, neither the field nor the workforce of early education is sufficiently prepared for the challenge of ensuring quality mathematics education for all young children at this time.

The field of early mathematics education is a rather new domain of study. In 2000, for the first time, the National Council of Teachers of Mathematics included standards for early education in their recommendations. Prior to this date, many early childhood teachers thought of early math as strikingly simple, consisting primarily of
counting and simple arithmetic (Copley, 2004). When the NCTM expanded the content of early math education in its recommendations, it surprised the early childhood community by stating that math for young children involves more than counting and simple arithmetic. Reading through the content strands identified by NCTM, few early childhood teachers understand their relevance to young children, since terms such as “algebra,” “data analysis,” and “probability” sound foreign to them. They have little idea, for example, what algebraic thinking looks like in the early childhood classroom and how to deconstruct this concept into the initial concepts that young children should learn. Though the recent development of the Common Core State Standards in many ways unifies the early childhood mathematics objectives, they are limited in scope, especially for pre-kindergarten (Common Core State Standards Initiative, n.d.; Illinois State Board of Education, 2013). The field is also ill-equipped to describe effective mathematics practice in early childhood classrooms (Baroody, 2006; Donovan & Bransford, 2005; National Research Council, 2001). This leads to inconsistencies and ineffective instructional practices (Clements & Sarama, 2008; Klein, Starkey, & Wakeley, 2004).

Teacher competence in mathematics teaching poses the second challenge to the provision of quality early math education. Specific characteristics of teacher preparation contribute to this challenge. Unlike teacher preparation in middle or high schools, certification for early childhood training does not require specialization by subject areas (National Research Council, 2009). As a result, degree program training in early childhood mathematics is provided in various ways—occasionally there is a whole class on teaching math, but more frequently there is a single class devoted to both early math
and early science. Sometimes, early math is only a small part of an integrated curriculum that includes literacy, science, social studies, music, and visual arts. Consequently, teachers of young children, even with a bachelor’s degree in education, have much less pre-service training in mathematics teaching than teachers in upper grades.

Inadequate preparation likely contributes to the uncertainty among early childhood teachers about their mathematics knowledge and their low confidence in teaching the content. In fact, many early childhood teachers choose to work with preschoolers as a way to escape from having to teach “hard” mathematics (Copley, 2004). The joint position statement on preschool math by the National Association for the Education of Young Children and the National Council of Teachers of Mathematics supports this view, noting that the general lack of preparation contributes directly to poor attitudes toward and low confidence in mathematics teaching among early childhood teachers (NAEYC & NCTM, 2002).

Lack of confidence appears to feed an unfortunate tendency to avoid teaching math in classrooms. A study done by the National Center for Early Development and Learning (Clifford et al., 2005) examined the time spent on mathematics in pre-kindergarten rooms across six states. The results show that in contrast to time spent on literacy, very little time in the classroom was spent on mathematics, only about 6.5% of the day. A study of Chicago early childhood classrooms found similar results. Ninety percent of teachers conducted literacy-related activities daily, but only 21% carried out mathematics activities (Ross et al., 2008). What is more, when math lessons are offered in early childhood classrooms, they are most likely to take place during large group time. Rarely is mathematics fully integrated into play activities, snack time, or transition.
Teachers’ attention to individualized mathematics learning is scarce in early childhood classrooms (Sparr, Chen, & McCray, 2011). In many classrooms, children are simply asked to memorize procedures and learn basic facts through rote learning (Baroody, 2006; National Research Council, 2009; Pianta et al., 2005). Deep and sustained interactions with mathematical ideas are a rare occurrence (NAEYC & NCTM, 2009, 2010). Clearly, instruction in early math is not keeping pace with the growing recognition of the importance of the early mathematics experience (National Research Council, 2009).

The field needs to gain a better understanding of effective practice in early mathematics and teachers need help in the form of concrete techniques grounded in research. How can mathematics instruction in the early childhood foster the development of mathematical understanding in young children while still being meaningful and engaging to the child?

Developing Children’s Mathematics Concept Knowledge through the Use of Teachers’ Mathematics Language

Researchers have made several promising suggestions for the improvement of early mathematics instruction: integrate more mathematics learning throughout the day, use developmentally appropriate mathematics manipulatives as tools for instruction and broaden the scope of mathematical content by addressing more strands, etc. Of these strategies, one major proposal that shows specific promise is teachers mindfully promoting mathematical concept knowledge in young children (Ginsburg, Lee, & Boyd, 2002; NAEYC & NCTM, 2009; 2010; summary in National Research Council, 2009). Concept development focuses on developing metacognitive skills that enhance the
thinking processes, executive functioning skills, and mathematical understandings of young children, rather than simply teaching math facts (Baroody, 2006; Mayer, 2002; National Research Council, 1999; Pianta et al., 2007). Advocates of concept development argue that it is critical to early mathematics learning because it promotes the acquisition of usable knowledge that can be applied to new and different situations (Copley, 2000). Researchers argue that teaching children to develop conceptual understanding deepens young children’s mathematics learning in a way that is necessary if we want them to have an adequate foundational understanding (Clements, DiBaise & Sarama, 2004).

Currently, early mathematics is often taught through teacher-directed instruction that emphasizes facts and procedures (Baroody, 2005). Conceptual mathematical knowledge, in contrast to this procedural mathematics knowledge, is “richly connected to mathematical thinking that embodies information about relationships between things” (McCray & Chen, 2011, p. 255). “While the larger mathematics education community has made a lot of headway in ‘redefining mathematics as a dynamic discipline full of opportunit(ies) for inquiry and discovery,’ the early childhood community has not yet gotten the message” (Feiler, 2004, p. 399, cited in McCray & Chen, 2011). The need to promote concept understanding in early mathematics, as opposed to just encouraging the memorization of math facts, is detailed throughout the literature (Baroody, 2006; McCray & Chen, 2011; National Research Council, 2009).

I have seen this first hand in my work as an administrator. Once in an interview in 2012, I asked a seasoned early childhood teacher to describe how she taught mathematics. She replied excitedly that her children could identify numbers because they
completed their workbook pages. They were great at tracing numbers. However, the teaching of mathematics is so much more than recalling numbers visually or tracing them in a book. I was interested in how she taught the children the concept of numbers, how she got at the idea of number with her questioning. The teacher could not articulate the difference between memorization and conceptual understanding in mathematics. In practice, the push towards standards and teaching content in early childhood sometimes overshadows the need for children to develop conceptual understanding in a way that is meaningful and engaging. I believe we can do both and we need to do both.

One important way teachers promote mathematical conceptual understanding is through the use of their language (Klibanoff et al., 2006; Rudd, Lambert, Satterwhite, & Zaier, 2008). Teachers’ language is an extremely vast topic but the important point is that research shows that this language does matter to children’s learning. In my work in classrooms and with teachers I find myself always going back to language. It is so central to our interactions, our work with students and how we teach in early childhood. Language is often discussed in terms of quantity alone (how much talk a child hears). However, language is a method of bringing the teacher and the child together in the learning context. It is a way to construct knowledge through social interactions (Vygotsky, 1986).

In a broad sense, the deliberate use of language helps teachers intentionally articulate concepts. Discussions between the teacher and the child make concepts more accessible to the student and they increase understanding (Bodrova & Leong, 2007; Burchinal et al., 2008; Dickinson & Tabors, 2001; Durden & Dangel, 2008; Guo et al., 2011). Language is also a tool for feedback (Pianta, Le Paro & Hamre, 2008). It is
through language that teachers can verbalize a concept, deepen understanding by giving information, and ask questions that trigger higher-level thinking (Bodrova & Leong, 2007; Dickinson & Tabors, 2001; Durden & Dangel, 2008). Thus, these sustained in-depth interactions create greater meaning for the child. Although most teacher language research is not content specific, the importance of teachers' language as an effective tool in instruction is well established (Blank, Rose, & Berlin, 1978; Durden & Dangel, 2008; Dickinson, McCabe, & Sprague, 2003; Dickinson & Snow, 1987; Wilcox-Herzog & Kontos, 2001).

The little research that has been done on the role and impact of teachers' mathematics language in the preschool classroom is promising. Klibanoff et al. (2006) studied the frequency of "mathematically relevant input" in areas such as counting, cardinality, equivalence, and number symbols (pp. 4-5). They found that teachers who exposed their students to more “math talk” had students with greater mathematical gains across the school year. Other studies also indicate that the mindful and more frequent use of teachers’ mathematics language relates to children’s mathematical achievement and can promote conceptual understanding (McCray, 2008; Rudd et al., 2008).

More research is needed to help teachers use math talk explicitly. The studies that have been done on teachers’ mathematics language in the early childhood classroom offer a surface level analysis of the language use. While the discussion about frequency of teachers’ mathematics language and child outcomes clearly indicates a positive relationship, the analysis to date doesn’t provide a comprehensive understanding of the elements of language (type, context and complexity) occurring in classrooms and how they relate to children’s conceptual knowledge (Klibanoff et al., 2006; National Research
Council, 2009; Rudd et al., 2008). Teachers’ language is so much more than just the frequency of words.

Current research does not provide an appropriate description of the types of mathematics language (such as utterances related to geometry, and measurement) that might be effective. It doesn’t help teachers think about the context (large group, small group and free play) in which the language is being used. Finally, it doesn’t pay attention to the quality of the cognitive interchange (how the language engages the child in higher-level cognitive thinking) between the teacher and the child. For example, some language only calls on the child to repeat a word (low-level cognitive demand) while a question about how something happened asks the child to think about a situation and develop their response (high-level cognitive demand). The proposed study aims to provide a review of the use of math language by early childhood teachers and address the issues neglected in the current research literature. The goal is to better understand which characteristics of teachers' math language connect to children’s development of mathematical skills and best promote concept development in young children. The exploration of these ideas will provide critical information about how to improve early mathematics instruction.
CHAPTER II
LITERATURE REVIEW

Efforts to identify the elements of the instructional environment that are critical to children’s cognitive development in mathematics have paid specific attention to the language that teachers use in the early childhood classroom. Teachers’ talk is a vital tool that can have a significant effect on children’s understanding and development (Hart & Risley, 1992; Kontos & Wilcox-Herzog, 1997; Vygotsky, 1986). However, this is a simplistic statement about a complex element of the learning process. An examination of what words are used in the classroom, how they are used, and how language impacts children’s learning is essential in starting to explain the story of language use in the classroom environment. An examination of all of these elements is needed to devise professional development and create research strategies that will improve teaching (Bodrova & Leong, 2007; Durden & Dangel, 2008; Newman, Griffin, & Cole, 1989).

Teachers’ mathematics language in the preschool classroom is less studied than other forms of teacher talk. There are three major reasons why this might be true. First, there is a strong emphasis on literacy development during the early years of schooling. Mathematics instruction often gets less attention in both research and practice. The second, and a related point, is that there is a lack of recognition about the importance of math language in children’s learning due in part to the lack of research in this area. Teachers report not prioritizing mathematics in the classroom. Thus, they provide less opportunities for math learning in the classroom and also use significantly less
mathematics language throughout the day as compared to talk related to literacy (National Research Council, 2009).

A further challenge in the study of teacher math talk is the incomplete definition of what constitutes “mathematics language” in the preschool classroom. The very few studies that have examined this topic have commonly defined teachers’ mathematics language as the frequency of mathematics’ related words that teachers use (Klibanoff et al., 2006; Rudd et al., 2008). Even though some studies have demonstrated interesting connections between teachers’ mathematics language in the preschool classroom and children’s mathematics outcomes, there are several limitations to this category of work (National Research Council, 2009). It does not provide a comprehensive review of the various types of teachers’ mathematics language that are used in the classroom, where they are used, and how more thoughtful use of such language might contribute to enhanced conceptual development in children. There is far more to the story of teachers’ mathematics language.

To build the argument for why the study of mathematics language is a necessary endeavor, this chapter will start by focusing on teachers’ language in a more general sense, detailing the theoretical framework commonly used to explain the role that teachers’ language plays in the learning process and how it can be used as a tool in classroom practice. This explanation will be followed by a description of the research establishing the connection between teachers’ language and child outcomes. The discussion will highlight questions and findings that are presented by the literature in three key areas: (1) how the literature has examined the frequency of language input as it relates to child outcomes, (2) issues in the research examining the relationship between
language use in various instructional settings and how this potentially relates to child outcomes, and (3) the current thinking on how teacher language may function as a tool for cognitive change. These three elements are all necessary components in creating the complex picture of language in the classroom: how often the language is occurring, where it is happening, and the complexity of the language within the teacher-child interaction.

Though there are many elements that impact the learning process of the child (task, materials, peer interactions – to name a few), understanding the role language plays in the learning process will lay a foundation for examining the more specific (and less studied) topic of teachers’ mathematics language in the early childhood classroom. The second part of this chapter will provide a critical summary of the limited literature that exists on teachers’ mathematics language in the preschool classroom and its relationship to child outcomes. It will highlight the gaps that exist in the literature, setting the stage for the importance of the current study.

More detailed and nuanced attention to the variables that impact the relationship between teachers’ mathematics language and child mathematics outcomes will increase the field’s understanding of what effective early mathematics instruction looks like and help identify the instructional components that need to be targeted to improve early mathematics education. It will expand our conceptual understanding of teachers’ mathematics talk. The following description provides a starting point for understanding the power that language can hold, and the role that this element of practice can have on the internal process of concept formation within the individual child.
Theoretical Framework: Language as a Tool in Learning Process

Spoken language is central to both the teaching and learning processes in school (Cazden, 1998). Teachers’ language use in the classroom is a tool that can facilitate connections between objects, actions and ideas for children (Cross, Woods, & Schweingruber, 2009). But there is more to the story of language in the classroom than the discrete words that the child is exposed to. Learning is a complex process that takes place through rich and varied interactions over time. Language and its influence on the learning process cannot be summarized easily. However, there are a few key theoretical arguments that are relevant to this work. They will be described below, followed by a brief discussion of what is missing in the link between theory, research, and practice, regarding teachers’ mathematics language.

Socio-cultural theorists, such as Lev Vygotsky, argue that knowledge is socially constructed by individuals’ interactions with their environment; learning is a socially mediated process. Lev Vygotsky’s sociocultural theory is particularly relevant to this study because it connects the social world to the internal, cognitive process of the child. Vygotskian theory covers many areas, especially those regarding the teacher-child interaction, context and culture. Two very specific points will be discussed. They were selected because of their particular pertinence to this work: (1) cognitive change occurs through social interactions that are reciprocal, and (2) language is one of the main tools that facilitate cognitive change in the learning process.

Social Interactions

Vygotsky viewed development and learning as a process that occurs over time, and he described language as a tool in this process. In more concise terms, Vygotsky
strongly believed that cognitive change is a social process and that the child’s interactions within the environment are the impetus for individual change. This is the first major tenet. Vygotsky (1994) writes, “The entire history of child’s psychological development shows us that, from the very first days of development, its adaptation to the environment is achieved by social means, through the people surrounding him. The road from object to child and from child to object lies through another person” (p. 116). He goes on to connect these interactions to development, “This road-passing through another person-proves to be the central highway of development of practical intellect…speech here plays a role of primary importance” (p. 116). Social interactions are imperative to the child’s learning and development.

But how does cognitive change occur through social interactions? The first step is recognizing that this interaction is reciprocal. As opposed to behavioral theorists who believe children absorb knowledge through direct input, constructivists recognize that children are active learners whose prior experiences impact the learning process. “Cognitive change results from using cultural tools in social interactions and from internalizing and mentally transforming these interactions” (Schunk, 2014, p. 244).

Vygotsky took this belief a step further and described how “tools” facilitate the process of cognitive change. He writes:

All human psychological processes (higher mental processes) are mediated by such psychological tools as language, signs, and symbols. Adults teach these tools to children in the course of their joint (collaborative) activity. After children internalize these tools they function as mediators of the children’s more advanced psychological processes. (cited in Karpov & Haywood, 1998, p. 27)
The social environment is vital for learning and social interactions transform learning experiences.

**Language as a Tool**

Language is central to the social interactions that lead to cognitive change. Teachers’ language use is a major contributor to the mediation of joint activity, which connects individuals as they move toward the shared understanding that was described above (Kozulin, 2003; Newman, Griffin & Cole, 1989). Vygotsky describes the many ways language, being the most powerful tool in the social process of human development, supports cognitive development (learning). In simplistic terms, language is a tool that is used to convey and internalize meaning, to organize thoughts. Social speech moves to private speech, and to covert (inner) speech. This final step internalizes meaning within the individual. It is through language that social processes are changed to internal-cognitive processes. Vygotsky describes this process:

The greatest change in human development occurs when this socialized speech, previously addressed to the adult, is turned to himself, when, instead of appealing to the experimentalist with a plan for the solution of the problem the child appeals to himself. In this latter case the speech, participating in the solution, from an inter-psychological category, now becomes an intra-psychological function. The child applies to itself the… transfer of a social form of behavior into its own psychological organization…This complex path, followed by the child in his transition to the interiorization of social speech [is] the history of this process, is therefore, the history of the socialization of the child’s practical intellect, and at the same time, the social history of its symbolic functions. (cited in Van der Veer & Valsiner, 1994, pp. 119-120)

Vygotsky identifies this internalization of concepts as human development: “If at the beginning of development there stands the act, independent of the word, then at the end of it there stands the word which becomes the act, the word which makes man’s
actions free” (Van der Veer & Valsiner, 1994, p. 170). In Vygotsky’s eyes, when a person can articulate what he is doing, he can define it for himself and has a true understanding of consciousness. This process is a continuous cycle of understanding.

Language not only connects the social and psychological plane of the individual but it is the tool that allows the teacher and child to engage in shared experiences and start the process of internalizing conceptual understanding. The three key components in the observable social process are context, joint activity, and language; they are all interrelated through the learning process (Vygotsky, 1986). Vygotsky argued that, “Learning and development cannot be disassociated from their context. The way that learners interact with their worlds- with the persons, objects and institutions in it-transforms their thinking. The meanings of concepts change as they are linked with the world” (Schnuk, 2014, p. 244). When applied to school learning, the teacher plays a role in setting up classroom instructional contexts and creating moments for the child to engage in joint activity with other children, with the teacher, and with the materials provided in the setting. Through reciprocal interactions in the environment, children can gain meaning and understanding.

To explain more explicitly how talk functions to support learning let’s take an example from Mollie is Three by Vivian Paley (1986):

Mollie has another new word. “My story is about something that’s pretty curious,” she says. “What is the curious thing?” [the teacher] asks. “Not Curious George. Curious different curious. It’s a wolf and a little girl are buying some gum.” “That is curious. It’s unusual,” [teacher says]. (p. 105)
The child goes on to further experiment with the word “curious.” First, the child implements her prior knowledge and tries the word out within an interactive context. She relates it to the story as a descriptor. The teacher uses her questioning to clarify and extend meaning for the child. In her second response she acknowledges the child’s understanding of the word, and re-states it introducing new language and a connected concept by saying “That is curious. It’s unusual.” Discourse isn’t just about the specific words the teacher uses; it’s about the interaction. It’s about listening, responding, and extending the child’s words and actions; leading to learning through shared experiences. This reciprocal interaction between the teacher and child leads the child to integrate the word and it’s meaning into her private speech. She uses it with friends in play, she tries it out in different contexts, all the while processing and clarifying what this word might mean. Vygotsky (1986) writes that,

Word meanings evolve. When a new word has been learned by a child, it’s development is barely starting; the word at first is a generalization of the most primitive type; as the child’s intellect develops, it is replaced by generalizations of a higher and higher type- a process that leads in the end to the formation of true concepts….direct teaching is impossible and fruitless. (pp. 148-149)

Mollie might use “curious” in her pretend play; she might call her doll “curious” at night when she is talking in bed. Finally, the concept of “curious” becomes part of her inner speech. She can now use the word in new contexts, teach the word to friends, and build on its meaning. For example, Mollie might say her mother is acting “curiously” when she asks her about her day. The idea of the word is realized in Mollie’s mind and she can apply it to new situations. The interaction paved the way for the child to rethink and consider new ideas. As shown in this example, teacher talk is one part of the
dialogue of learning in the classroom environment. It is also an important element in the process of the child’s learning.

**Summary**

Vygotsky’s work not only emphasizes both the important role of teacher talk but also illustrates its complexities in the dynamic process of learning. It is about the content of the words teachers use, the contexts they are used within (meaning what they relate to in the real world) and how this language extends the child’s learning. Two of Vygotsky’s main ideas, how cognitive change occurs through reciprocal interactions and the importance of language as tool in the learning process, lay the foundation for understanding how teachers’ language impacts children’s cognitive development. They provide the argument for researching this element of classroom practice in the hopes that we can start to understand more about the complex role that language plays in children’s learning (Vygotsky, 1978, 1986).

Focusing on Vygotsky’s two main points enables the connection of his work to the state of the current research. Existing work on teachers’ mathematics language only focuses on the impact of teachers’ mathematics language on the child; it does not look at the reciprocal interaction piece that Vygotsky describes as a necessary component to the learning process.

Figure 1 illustrates the connectedness between context, teacher, and child within the classroom environment. Language is the purple circle. It is a tool that links all three components together and helps to facilitate the cognitive process of learning. Language is not directional, but reciprocal, in the interactions between the three represented elements.
In comparison, Figure 2 represents the current research on teachers’ mathematics language in the preschool classroom that will be explained in the coming chapters. It is presented here to illustrate the important theoretical elements that are missing from the existing research. The three circles, instructional settings (environment), teacher, and child are all separate.
Figure 2. Representation of Current Research on Teachers’ Mathematics Language in the Preschool Classroom

The first issue that emerges when comparing Figures 1 and 2 is that the current research examines all three circles independently. There is some suggestion of connection but the connection is not clear. Second, the research does not examine the reciprocal nature of the teacher-child interaction in the learning process. The large arrow in Figure 2 represents how the “interaction” through language is one-sided. More needs to be known about the components of the teachers’ language and how they influence children’s cognitive development. The story of learning in young children is multifaceted, and the presence of meaningful teacher talk makes it so the plot isn’t created by chance alone.
The Power of Words: Research on the Connection Between Language and Children’s Learning

This section elaborates on the research that has been done to study language use in action. Empirical studies support Vygotsky’s ideas. The literature has pulled the concept of language apart looking for details about how its use can increase children’s learning. The power of language as a tool is mediated by three factors that are relevant to this study and illustrated through the literature: the frequency of utterances (input), where the language occurs in terms of context, and the cognitive demand the language places on the child in the learning process. This section will describe the literature on each of these topics and summarize the questions that still exist in the field. It will highlight the relationship of these factors to the process of children’s learning and leaning outcomes, setting the stage for the more specific work on preschool teachers’ mathematics language that will follow.

It is important to note that the very concept of “language” is complex and it is rarely defined in uniform terms. There is a wide-range of methods of studying teachers’ language, from assessing how language provides social support to the child to the integration of standards through content specific words. The research reviewed in this work focuses exclusively on three methods of studying teachers’ language. These areas were selected because of their ability to connect the story of teachers’ language to children’s learning in the preschool classroom. The literature shows that the power of language as a tool is likely mediated by these three factors, but this work is also limited in many ways. The connections and the limitations will be discussed as well.
The Frequency of Language Input as it Relates to Child Outcomes

Observing the frequency of adult language use has been established as a popular method of assessing how language use impacts children’s outcomes (Cazden, 1998). This work is not specific to teachers’ language, but includes the frequency of parents’ language input (Levine, Gunderson & Huttenlocher, 2011; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2011). The literature shows that there are particular words, and particular categories of words, that if used in higher frequency relate to increases in specific child outcomes (Klibanoff et al., 2006). A few relevant studies, two related to math-specific words and one related to the amount of “sophisticated vocabulary” used, are given here as examples of the important role that the frequency of input children are exposed to during the early years relates to child outcomes.

Recent research from the University of Chicago has shown that the frequency of parents’ number talk with their young children is related to their understanding of number concepts and may impact their school achievement. Levine et al. (2011) observed parent-child interactions in 44 homes with children between the ages of 14 and 30 months. Across five 90 minute sessions parents used between 28 and 1,799 number related words in everyday activities. At the end of the study children who heard a greater number of math words performed better on number related tasks. The tests assessed the children’s knowledge of cardinal meanings of number words. For example, they were shown two pictures, one with three squares and one with two squares, and they were asked to point to the one with three. Levine noted that this early “edge” in mathematics ability could have an impact on success in school.
Another study noted a similar result based on the spatial input children were exposed to at home. Pruden, Levine and Huttenlocher (2011) studied the relationship between parents’ spatial words and children’s understanding of spatial relationships. They examined 52 parent-child dyads in their home setting to look at the amount of spatial language parents used across nine visits from when the children were 14 months to 46 months old. To code parents’ language they used the System for Analyzing Children’s Language about Space (Cannon, Levine & Huttenlocher, 2007), which looks at the frequency of shape terms, dimensional objects and spatial features. The children were assessed at 54 months using three non-verbal spatial tasks and their vocabulary was assessed using the Peabody Picture Vocabulary Test, 3rd Edition (Dunn & Dunn, 1997).

The researchers found that the variability in the parents’ input of spatial language predicted the spatial language the children produced at 54 months and that children who produced more spatial language performed better on spatial problem solving tasks (Pruden, Levine & Huttenlocher, 2011).

When the frequency of words is examined in the literature it isn’t always about the subject of those particular words, it is sometimes about the complexity of the words themselves. “Complexity of specific words” refers to words that are more advanced and less commonly used in conversation, for example: talking about the concept of “quantity” as opposed to just “more” or “less.” A recent study by Dickinson and Porsche (2011) audio and videotaped a sample of preschool teachers to look at their frequency of sophisticated (complex) vocabulary use and how the teachers engaged children in discussions that were rich in language. They found that the frequency of sophisticated vocabulary used by preschool teachers, i.e. using more advanced vocabulary words and
engaging children in discussions about these words, predicted children’s vocabulary growth the following year in kindergarten and this correlated to fourth grade reading abilities. This study offers a different definition of “language.” It suggests that the effect of language doesn’t happen just by exposure to words, it is also about the engagement of the child and how the language enhances the learning process for that individual. Though it did not measure it directly, this study suggests that language that is more complex engages the child in a different way than less cognitively demanding language.

These studies are a sample of the work that has shown significant connections between the frequency of language input children receive in the early years and later achievement. This work, though an important piece, is limited in that it only examines one part of the equation in understanding the role of language in the learning process. Research shows that other related components in the classroom environment also impact the relationship between the input children receive and their outcomes (Montie, Claxton & Lockhart, 2007).

**Instructional Settings, Teachers’ Language, and Child Outcomes**

The literature indicates that instructional settings are relevant to the discussion of teacher language and child outcomes. Several studies have described and examined the relationship between instructional settings in the classroom environment and children’s outcomes (Durden & Dangel, 2008; McCray, 2008; Montie, Claxton & Lockhart, 2007). There is talk in the literature about small group being the most effective setting for teaching, and how the use of this setting leads to higher child outcomes. Second, the research points to the idea that teachers’ language might have a differential impact on child outcomes in different settings (Bredekamp & Copple, 1997; Durden & Dangel,
A few studies attempt to quantify this idea by making generalizations across teachers and classrooms (McCray, 2008; Montie, Claxton & Lockhart, 2007). However, this is the main issue: the connections made in both of these points are generalizations based on little empirical research.

Though the studies suggest instructional settings relate in some way to children’s outcomes, the findings that exist are broad assumptions that don’t explain how settings mediate the relationship between teacher language use and children’s outcomes in classrooms. In order to explain this connection, far more needs to be known about the process. This section will summarize the literature on the connection between instructional settings, teachers’ language use, and child outcomes. It will also provide questions that need to be examined further based on the present research.

**Definitions of instructional settings.** Instructional settings define the context that the learning process takes place within. A large body of literature on instructional settings focuses on describing the three major classroom learning formats: whole group, small group, and free play. In examining each of these instructional contexts, researchers tend to look at the role and relationships of teachers and students in each context (Durden & Dangel, 2008; Epstein, 2007; Mashburn et al., 2008; Sheridan, 2007). The very definition of each context is based upon the dynamic of the relationship afforded by each.

The whole group setting is typically defined as the context in which the teacher leads an instructional activity while every child in the class participates (Clayton & Forton, 2001). The main type of whole group activity in preschool is usually called “circle time” or “meeting” (Lown, 2002; Wald, 1994). The instructional context of small group in U.S. preschools is usually conceptualized as a mix of adult-planned and child-
in-charge activity in which the teacher selects the group, creates the context, and involves the children in the learning process. In a small group, the teacher usually works with two to eight students around a common goal and there is more often an on-going exchange of language (Berk & Winsler, 1995; Durden & Dangel, 2008; Wasik, 2008). Free play is generally described as a setting in which students are given the opportunity to guide their own learning by exploring various materials in their environment and interacting with their peers (Frost, Wortham, & Reifel, 2001). In the literature, free play is defined as a child-guided period of open choice where the students take the lead and the teacher supports exploration and social interactions (Hirsh-Pasek et al., 2009; Kontos, 1999; Mueller, 2004). Though every teacher develops her own unique pattern of interactions in each setting, the unifying factors stated above enable researchers to compare and contrast the use of settings across classrooms.

**Empirical research.** The current literature indicates some possible connection between instructional settings and children’s outcomes. There are very few studies that attempt to quantify a specific element across various settings and how this element impacts children’s outcomes. However, instructional settings only have a mediating effect on child outcomes. It is about how the teacher uses a specific setting, and the interaction that occurs within that setting. Research in this area is a more specific attempt to shed light on how the use of a particular “setting” may impact children’s outcomes. Several studies will be explained to illustrate this connection. Elements such as time, task, and teachers’ language are used to analyze the power of comparative settings on children’s outcomes (Connor, Morrison & Slominski, 2006; McCray, 2008; Montie, Claxton & Lockhart, 2007; Morrow & Smith, 1990; Phillips & Twardosz, 2003).
One study indicated that the amount of time spent in each setting can impact children’s gains. Montie, Claxton and Lockhart (2007) performed a multinational study across ten countries with 18,000 students. They examined the amount of time students spent in each instructional setting in preschool and connected this with later child outcomes. They found that children had higher cognitive scores at age seven when their classrooms at age four had less whole group activities, and more small group and free play activities. Children also did better on later language assessments when their preschool classroom emphasized free play. This study illustrates the relevance of settings in the discussion of children’s outcomes. It indicates that it is more valuable for children to spend time in the instructional setting of small group, and especially in free play, during the preschool years. It also shows that there are potentially differentiated impacts of the use of instructional settings in early childhood on children’s outcomes, leading researchers to seek a more specific answer about what elements of practice might vary across settings, and how they might lead to differential effects.

In the few studies that have actively compared child outcomes based on specific task completion across small group and whole group contexts, differences have been found. Phillips and Twardosz (2003) found that the average number of teacher directed comments per child doubled when reading was done in a small group setting as compared to whole group (meaning that there were significantly more questions and comments used by the teacher in the small group setting). Children also participated more by pointing, pretending, and holding the book when in small groups. The researchers concluded that reducing group size and teaching in small groups leads to an increase in student participation, and a suggestion of higher child outcomes. This research is interesting in
that it suggests there may be some differences between how language use is differentiated based on context.

Even though this study only hypothesizes the connection, other studies have shown that small group instruction is more likely to have a larger effect on child outcomes than whole group or free play (Dickinson & Smith, 1994; Karweit & Wasik, 1996; Morrow, 1988). One study by Connor, Morrison and Slominski (2006) illustrates this effect. They observed 156 preschoolers across 34 classrooms, coding the instructional time each child spent in various learning contexts. They assessed children’s skills in a variety of literacy activities including alphabet tasks, letter-word recognition, and vocabulary. The researchers found that the effect size of instruction on child outcomes on these tasks was ten times greater when it took place in small groups as opposed to whole group. Morrow and Smith (1990) also found that children learned more vocabulary words and had higher comprehension in story reading when the lesson was done in small group compared to whole group. Even though small group has been largely viewed as an effective learning context, it is rarely used in early childhood classrooms (NCEDL and ECLS-K in National Research Council, 2009). This leads us to some interesting questions: what does teachers’ language look like in this setting and how does it relate to child outcomes?

Although the conceptualizations of each setting are merely generalizations across classrooms, the literature supports the idea that different types of language dynamics occur in each of the three settings (Bredekamp & Copple, 1997; Morrow & Smith, 1990), supporting the argument that instructional settings must be part of the discussion on teacher language use in the classroom. Defining one type of teacher language in each
setting is a problem since teachers create their own pattern of interactions within each moment. However, this doesn’t mean that there aren’t any similarities across teachers; we just have to remember that the definitions are in fact generalizations and that it is problematic if they are taken as constants.

The whole group setting typically has a lot of teacher directed language as compared to the other learning formats. Teachers almost always have specific instructional goals that they plan to meet through the use of the whole group setting (Maloney, 2000). The small group is commonly viewed as the most effective setting to teach content development in preschool because it is thought to foster an active role for the child, contain an increase in tailored instruction by the teacher based on individual needs, and allow for teacher language to be more accessible (Berk & Winsler, 1995; Moll & Whitmore, 1993). A statement by the National Research Council (2009) summarizes the issue, “The almost non-existent use of small groups in early childhood programs…is of great concern given that small group instruction has been found to be an effective context for enhancing young children’s learning” (p. 247). However, there is little empirical evidence to support how the use of small group impacts children’s learning outcomes.

Similarly, the research on teacher talk during free play is usually based on noted observations as opposed to empirical evidence. The literature describes teacher talk in this setting as varying widely. It usually has a larger range of simple to complex language compared to teacher talk in other settings (Burman, 2007). Through classroom observations, Kontos (1999) found that teacher talk varies based on play activities. Language usually focuses on three elements in this setting: describing objects or
materials that children are manipulating, assisting children in acquiring self-help skills, and negotiating social interactions. Teachers can productively enhance children’s play by asking open-ended questions and making statements that expand on what the child is doing in both social interactions and with materials (Howes, 1990). Several studies have found that teacher language that arises out of careful observations of child-directed activities is more complex and challenging and has a larger impact on child’s cognitive growth and competence then other types of language (Berk & Winsler, 1995; Durden & Dangel, 2008; Girolametto, Weitzman, Lieshout, & Duff, 2000; Kontos, 1999; Pellegrini, 1984).

Another study that will be discussed in more depth later looked specifically at the frequency of teachers’ mathematics words in various settings. McCray (2008) found that the context the teacher language was used in did have an impact on the relationship between these words and children’s mathematics gains. Only math-related language delivered during non-circle time showed a significant, positive relationship to child learning. The amount of math-related language during circle time showed no association with children’s gains. This study further confirms that settings may have some effect on the relationship between teachers’ language and child outcomes, though the extent of this impact is not clear.

The current literature indicates two things: that there may be some important differences across teacher language use in various instructional settings, and that these differences might be impacting children’s outcomes (Bredekamp & Copple, 1997; Durden & Dangel, 2008; McCray, 2008; Morrow & Smith, 1990). However, there are several questions that still exist in regards to the research on the relationship between
instructional settings, teacher language and children’s outcomes. As the previous work suggests, do instructional settings mediate the relationship between teachers’ language and children’s outcomes? If so, how does this happen? This work is especially limited in the area of early childhood and in content areas outside of literacy. The field needs more information about teacher-child interactions across different instructional settings in the preschool classroom, and how the conversational patterns in each impact the process of children’s learning. Exploring this connection will help bring the context, the teacher, and the child, closer together.

**Teacher Language as a Tool for Cognitive Change**

Twenty years ago, Hart and Risley (1995) came out with a landmark study about differences between low-income and affluent families. They attributed a large amount of the achievement gap between these two groups of children to the amount of parent language that children are exposed to during the early years. Though this study has been heavily debated, the field has maintained the fact that the quantity of words children are exposed to during the early years of life does impact children’s development. Recent work by Hirsch-Pasek (as cited in Quenqua, 2014), is one example of a growing body of research that discusses the importance of the quality of language interactions, adding an important element to the discussion on language and children’s development.

**Quality interactions.** Hirsch-Pasek’s study, though not yet published, examines language interactions between two year olds and their parents during play sessions. “Quality of communication accounted for 27% of the variation in expressive language skills one year later” (Quenqua, 2014, p. 2). The sample was comprised of sixty low-income 3 year-olds. They found that the, “quality of interactions involving words- the use
of shared symbols (“Look, a dog!”); rituals (“Want a bottle after your bath?”); and conversational fluency (“Yes, that is a bus!”) were a far better predictor of language skills at age 3 than any other factor, including the quantity of words a child heard” (Quenqua, 2014, p. 1). This work lays the foundation for discussing the impact of both the quantity and quality of language that young children are exposed to in specific environments outside of the home, such as the early childhood classroom.

Research shows that the type of language that is used by teachers’ and how it engages the child may be more important than the quantity of language and/or where it is used in the classroom environment. Newman, Griffin and Cole’s (1989) book, “The Construction Zone: Working for cognitive change in school,” explains what the process of cognitive change is and how language factors into it. These authors argue that cognitive change arises from the interaction between people. In their words, “We use it to characterize a process involving a dialectical interaction between the social world and the changing individual” (p. 59). Teaching cannot just be the direct transmission of knowledge. Like Vygotsky (1986) argues, cognitive change happens through social interactions, discussions between people in the physical world. The external stimulus of what the teacher says and the internal process by which the organism incorporates these external events into existing mental structures is the method of change.

To understand how and why teacher talk contributes to children's learning, it is necessary to differentiate the types of language that teachers’ use. A majority of the research on teachers’ language in the preschool classroom focuses on this topic. The work shows that teachers’ words, statements, phrases, and questions facilitate the learning process for the child (Newman, Griffin & Cole, 1989).
In the book, “The Classrooms All Young Children Need: Lessons in Teaching from Vivian Paley,” Cooper (2009) discusses the power teachers have in helping children construct knowledge by drawing out their ideas, creating meaning through discussions, and connecting thoughts through conversations and storytelling. This is a complex process. One important point is how teachers’ verbal support can, “extend or deepen the children’s social, cognitive, and linguistic capacities” (p. 51). The teacher must “relinquish control over what the children should be thinking and actively embrace what they are thinking, individually and as members of a group. This requires that she ask both specific and general questions of what the children do and say” (pp. 50-51). This describes how teachers must position themselves in the discussion with children. Questions are a key way of deepening children’s knowledge and creating higher-level understandings. They require the learner to pull on what they already know, leading them to develop their own knowledge independently (Mulcahey, 2009).

The next section provides examples of how types of progressively more complex teacher language are defined in the research. The three examples of categorizing teacher talk were selected because they are heavily used in the literature. This section will also show how cognitively challenging teacher language has been found to have a positive impact on students’ learning. The major gap in the research is also discussed, specifically the lack of research that exists on cognitively demanding teacher language related to content areas outside of literacy in the early childhood classroom.

**Categorizing teacher talk.** In the research “teacher talk” is usually described in terms of form and complexity. Form is about the rules and conventions of the language (grammar and syntax are illustrations of this). For example, a statement is, “You have
blue shoes,” while a question is, “What color are your shoes?” These are different forms of language. Complexity is about the intellectual effort required to understand a given communication. It isn’t a function of the grammar, but it is about the substance and what thinking the phrase provokes in the child. For example, “Is this a triangle?” is a question that has less complexity than, “Why is this a triangle?” The latter places significantly more demand on the child (Blank, Rose, & Berlin, 1978; Pianta, Le Paro, & Hamre, 2008; Wilcox-Herzog & Kontos, 2001).

Cognitively demanding language challenges children to develop higher-level thinking skills that make them active learners (Cross, Woods, & Schweingruber, 2009). Varying by form and complexity, cognitively challenging teacher language has been repeatedly found to have a positive effect on students’ learning (Blank, Rose & Berlin, 1978; Burchinal et al., 2008; Dickinson & Tabors, 2001; Hedrick, Haden & Ornstein, 2009; Massey, 2004). To get more specific, cognitively demanding language is language that requires a child to use complex thinking in order to respond to the question or statement. It is based on the complexity of the interaction between the child and the adult and what the language is asking the child to do. For example, asking a child “Is that a block?” only requires the child to look at the object and respond based on observation of an item; asking “How did you build that?” requires the child to think about what they put together, think about how they did it, and then respond in a way that makes sense to the observer. The answer to the first question, “Yes,” is much more simple than the answer to the second question, “I found the blocks and then figured out that I could balance them on one another. Then I put them all together and made my
castle.” The second answer leads more easily into a “feedback loop” with the adult since it provides more information for the teacher to respond to.

Since such a significant portion of the work on teachers’ language examines the complexity of teachers’ talk and its relationship to cognitive growth in children, it is necessary that some of the predominant categories for differentiating types of talk in the literature are discussed. This literature is not intended to empirically test the link between teacher language and child learning, the connections are more speculative based on theory and observation. As we move towards a more detailed conceptualization of what effective teacher mathematics talk in the early childhood classroom looks like and how this has been linked to children’s learning outcomes, the relevance of this literature will come into play. Following are three detailed descriptions of classification schemas Wilcox-Herzog and Kontos (2001) used to categorize the cognitively demanding nature of teachers’ language: directives, non-elaborative statements, and elaboratives. They argue that form and complexity are related and they differentiate language based on the teachers’ intended purpose.

The first example they give is the use of a directive. A teacher uses directive language when she or he explicitly tells the child what to do, for example, “Sit on the rug,” or “Listen to me please.” This type of language is used primarily to direct the action or behavior of children. It is also used to manage the social environment of the room by controlling the flow of the classroom, establishing boundaries and rules, and managing disagreements. According to Wilcox-Herzog and Kontos (2001), directives are central to the process of classroom management.
The second type of language is called non-elaboratives (Wilcox-Herzog & Kontos, 2001). This occurs when the teacher does not provide additional information but merely asks closed questions and/or makes declarative statements based on observation. For example, “What is in that truck?” or “I see you built a tall structure.” Non-elaboratives serve a number of instructional and communicative functions: to ask a child to make a specific observation, to show recognition to a child, and for the teacher to indicate that they heard a child’s statement or question. Although this type of teacher language may not be apt to engage children in higher order thinking skills it is useful in directing children’s attention to certain learning facts and acknowledging their learning processes or products.

Elaboratives occur when the teacher asks open-ended questions and/or makes suggestions. Examples of elaborative statements are “How did you build that?” and “Why did you decide to mix those two colors?” Elaboratives are thought to foster a higher level of cognitive understanding in children because they require children to form a more complex response than directives and non-elaboratives do. As instructional language, elaboratives are also believed to promote content understanding because they encourage children to think through their intellectual process (Kontos & Wilcox-Herzog, 2001).

While Kontos and Wilcox-Herzog (2001) provided three general categorizations of teacher language, Blank, Rose and Berlin (1978) offer another means of categorizing teacher talk in the classroom by focusing exclusively on prompts that elicit child talk (most of which are in the form of questions). Questions are often viewed as the type of teacher language that is most critical to children’s learning process and engagement.
They base their levels on the cognitive demand that each prompt places on the child, focusing less on teacher intention and more on child reaction, though they are related. Blank, Rose, and Berlin (1978) describe four types of questions that teachers use to facilitate conversations with children, each category of language being progressively more complex and involving increasingly higher order thinking skills from the child.

Level 1 in Blank, Rose, and Berlin’s (1978) model is labeling. A teacher’s language at this level might be a question asking a child to identify an object or an attribute such as “What is this?” or “What color is this?” Children’s answer to such questions can be as short as one word or one phrase. These questions elicit a very simple response that is based on the child’s own observations or experience. They do not challenge children to think, reflect, or investigate. Unfortunately, this type of teacher question dominates in the preschool classroom, especially in mathematics instruction (Ginsburg, Lee & Boyd, 2008; Rudd et al., 2008). A teacher’s question at Level 2 also requires a low-level cognitive response, as it emphasizes description and recall. For example, “How did you get to school this morning?” or “Can you tell me what you ate for lunch?” Such questions ask the child to remember or describe something that is not directly in front of them. The child’s responses rely on memory. No higher order thinking skills such as analyzing and synthesizing are necessary (Blank, Rose, & Berlin, 1978).

Compared to the first two levels, teacher questions at Levels 3 and 4 in Blank, Rose, and Berlin’s (1978) model presents more opportunities to engage children in higher order thinking skills. Level 3 asks the child to infer, make comparisons, and/or summarize. Teacher questions might be a prompt to summarize a story or provide a
judgment, such as “What happened at the end of that story?” or “Why did you decide to draw a picture of your birthday party?” These questions require the child to process information and form their own opinion. They are also open-ended, requiring more than a one-word answer.

Level 4 teacher language is the most cognitively complex for children because these questions and statements ask them to reason, solve problems, and/or explain concepts (Massey, 2004). Level 4 language might include questions such as, “How do you think they came up with that solution?” or statements that ask for explanations, “Tell me about how this game that you created works.” In order to respond to these types of statements, a child needs to engage in a range of cognitive processes, including comparison, analysis, meta-cognition, reasoning, and perspective taking, to name a few.

Level 1 and Level 2 language reinforces children’s basic understanding of classroom routines and concepts. Levels 3 and 4 elicit higher level thinking skills and encourage problem solving (Blank, Rose & Berlin, 1978; Massey, 2004).

Another more recent study by Durden and Dangel (2008) examined cognitively challenging language as well through interviews, observations and videotaping. Their categorization of teachers’ language (see Table 1), is similar to Blank, Rose, and Berlin’s (1978) conceptions, except that they specifically examined language in preschool classrooms during small group time. Both studies qualitatively analyze the cognitive demand placed on the child by teacher prompts. Durden and Dangel (2008) found that the lead teachers they observed used mainly low-level cognitive language in small group activities. They concluded that teachers should be more aware of their language,
“including its purpose and opportunities to facilitate cognitively challenging conversations with young children” (p. 1).

Table 1. Examples of Levels of Cognitively Challenging Language during Small-Group Activity (Durden & Dangel, 2008)

<table>
<thead>
<tr>
<th>Level of language</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low level: Yes-no question</td>
<td>Would you like more paper?</td>
</tr>
<tr>
<td>Medium level:</td>
<td></td>
</tr>
<tr>
<td>Label</td>
<td>What is this?</td>
</tr>
<tr>
<td>Describe</td>
<td>What do these look like to you?</td>
</tr>
<tr>
<td>Recall</td>
<td>What do these remind you of?</td>
</tr>
<tr>
<td>Request information</td>
<td>What do they make peanut butter out of?</td>
</tr>
<tr>
<td>High level:</td>
<td></td>
</tr>
<tr>
<td>Hypothesize</td>
<td>What do you think this is?</td>
</tr>
<tr>
<td>Compare</td>
<td>What other...</td>
</tr>
<tr>
<td>Imagine</td>
<td>Guess what happened when…</td>
</tr>
<tr>
<td>Opinion</td>
<td>Do you like this?</td>
</tr>
<tr>
<td>Evaluation</td>
<td>What do you like about this?</td>
</tr>
<tr>
<td>Possibility</td>
<td>Could we do this?</td>
</tr>
</tbody>
</table>

This literature is lacking in two areas that are relevant to this study. Only Durden and Dangel’s (2008) study focused on early childhood. Two of the three categorizations of language explained above only speculate at the connections to child outcomes. Most of the work that has been done directly connecting teachers’ language use to children’s learning outcomes is similar to this in that it is more general in nature and does not focus on one content area; if it does, that area is typically related to literacy instruction.

Summary

The literature shows that the power of the relationship between teachers’ language in the classroom and children’s learning is mediated by at least three factors: the
frequency of teachers’ words, the context in which the language occurs in the classroom, and the cognitive demand that the language places on the child. All three of these factors are necessary to understanding the story of teacher language in the classroom.

However, the literature on teachers’ language leaves many questions unanswered about how each of the elements impacts the relationship between teacher language and children’s outcomes, especially in the early childhood classroom. As stated above, most of the work that has been done looks solely at the use of language in literacy instruction. Very little is known about how to define, much less assess, teachers’ mathematics language in the classroom outside of frequency of utterances. The following section will give an in-depth look at the empirical research that exists on teachers’ mathematics language in the preschool classroom.

**Empirical Studies on Teachers’ Mathematics Language in the Preschool Classroom**

Children’s achievement in early mathematics is connected to long-term outcomes in both mathematics and literacy (Duncan et al., 2007; Jordan et al., 2007, 2009). Preschool teachers’ mathematics language has been found to predict children’s mathematics outcomes (Klibanoff et al., 2006; McCray, 2008), but there are only a few empirical studies that have examined preschool teachers’ math language. This section will summarize the findings from these studies and highlight some of their issues.

In an important demonstration, Klibanoff and colleagues (2006) showed the positive relationship between teachers’ math talk in their preschool classrooms and children’s gains in mathematical knowledge over the course of a school year ($r=0.031$, $p=0.008$). They coded teachers’ mathematics talk based on nine types of language, all of
which referenced number and operation strands (for example, counting, cardinality, equivalence, nonequivalence, and number symbols). The researchers coded the mathematics language of 26 teachers across 13 preschools in the Chicago area. Language samples were collected from teachers during a typical school day. The observer visited each classroom for 2.5 to 3 hours. The coding of language began at the start of circle time and lasted for one hour, including a range of classroom routines and instructional time. The researchers also assessed 140 children at two time points (the beginning and end of the preschool year), using a short 15 item multiple-choice test of general mathematics knowledge.

Klibanoff et al. (2006) found that there was a wide range of types of mathematical word frequencies among the 26 classrooms (a range from 1 to 104 inputs, with an average of 28 math words used in that one hour). In addition, frequency of teachers’ mathematics talk was associated with gains in children’s mathematical skills. The study suggests that teachers’ mathematical language might play a critical role in the development of children’s mathematical competence and be related to children’s math gains.

In 2008, McCray conducted another study concerning teacher math language and child math learning. McCray extended the previous work by examining the impact of instructional settings (specifically the frequency of math words in circle time and in non-circle time) on the relationship between Head Start teachers’ math language and child outcomes. In McCray’s study, data was collected from 26 Head Start teachers and 113 children. The teacher language sample was drawn from the start of circle time and the following 60 minutes and coded based on the categories from Klibanoff and colleagues.
McCray reported two findings: first, in attempting to replicate Klibanoff et al.’s (2006) findings, analysis indicated that combining the two language measures (frequency of teacher language in circle time and frequency of teacher language in non-circle time) dilutes the effect of teacher language on child outcomes. The total frequency of math-related teacher language was not significantly related to child outcomes. The second result offered an additional insight: specifically, only math-related language delivered during non-circle time showed a significant, positive relationship to child learning. The amount of math-related language during circle time showed no association with children’s improvement (McCray, 2008).

This study offers insights into the connection between the frequency of teachers’ mathematics language and its relationship to child gains. Instructional setting interacts with teachers’ math-related language, mediating its effectiveness. Only the instructional setting of circle time was isolated for study in McCray’s (2008) work, in all other studies instructional settings were grouped together. The question remains: is the frequency of teacher mathematics language affected by other instructional contexts such as small group or free play?

In reflecting on these two studies, they are consistent in how they define teachers’ mathematics talk. Preschool teachers’ math talk is exclusively defined in terms of the frequency of teacher words in the number and operation strands (Klibanoff et al., 2006; McCray, 2008). This is a limited definition of teacher mathematics talk in two ways: it does not consider other mathematics strands (such as geometry) and it is solely based on
the specific words teachers utter, not accounting for the level of cognitive demand presented by each utterance.

Rudd et al.’s (2008, 2009) work takes a beginning step in looking at the level of cognitive challenge reflected in the language of mathematics talk. They coded the math language of eleven teachers from the Child Development Center at Southwest University. Each teacher was observed twice a week for four weeks. Every observation lasted thirty minutes and occurred in the morning or late afternoon. Rudd et al. argued that some math content strands are more challenging to the students than others. They coded language based on the hierarchy of complexity of mathematical concepts and how challenging the specific mathematics words were to the student. A total of 2,173 mathematics utterances were coded.

Rudd et al. (2008) used an Observational Coding Matrix (OCM) to track the frequency of teachers’ mathematics language in six classrooms that had children ranging from birth through age five. They wrote that the OCM was adapted from The Young Child and Mathematics from NAEYC (Copley, 2000). It includes eight categories of language defined by mathematics strand (see Table 2). This measure was designed to track the content area of the teacher's math language, and provide some insight into the variety of high and low-level conceptual language that is being used by the teacher. The division between low-level and high-level conceptual language was made based on the strand associated with each mathematical utterance. Low-level categories included spatial, number and geometry and high-level categories were operations, seriation, measurement, patterns, and display. They found that there was very little math
instruction occurring in any of the classrooms and that most of the language fell into the low-level conceptual language category.

Table 2. Language of Math Coding Categories and Examples (Rudd et al. 2008)

<table>
<thead>
<tr>
<th>Math category</th>
<th>Example of skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Level Number</td>
<td>Counting or labeling amount of objects</td>
</tr>
<tr>
<td>Spatial Geometry</td>
<td>Describes object locations with spatial words (e.g. in, on, between, under, over, behind, etc.)</td>
</tr>
<tr>
<td>Geometry</td>
<td>Recognizes, names or matches 2-D (basic) and 3-D (advanced) shapes</td>
</tr>
<tr>
<td>High-Level Measurement</td>
<td>Recognizes and labels measurable attributes of objects</td>
</tr>
<tr>
<td>Seriation/ordinal</td>
<td>Ordering of events or objects</td>
</tr>
<tr>
<td>Operations</td>
<td>Adds or subtracts using counting-based strategies</td>
</tr>
<tr>
<td>Pattern Displaying</td>
<td>Notices and copies simple repeating patterns</td>
</tr>
<tr>
<td>and Analyzing Data</td>
<td>Sorts objects and counts and compares the groups formed. Helps make simple graphs.</td>
</tr>
</tbody>
</table>

Rudd et al.’s (2008) work makes two important contributions to understanding the relationships between teachers' math talk and children's math learning outcomes. First, there does not seem to be a significant amount of mathematics instruction occurring in preschool classrooms, and most of the language occurring is related to number or spatial relations. Second, their conceptualization of teachers’ mathematics language moves beyond using frequency of teachers’ mathematics words. They introduced the idea that there is a range of cognitively challenging math language that is used by all teachers, and it can be defined in different ways. However, Rudd et al.’s scale defined varying complexity based on progressively challenging math topics, as opposed to form and function of the language phrases. This approach is contradictory to
other work in how it defines complex language. The majority of literature defines cognitively demanding language differently, based on how the teachers’ words engage children in conversations and promote more complex thinking processes within the child. Rudd et al. look at the complexity of just the math concepts represented by the words, not at the interactive process the language provokes (Blank, Rose & Berlin, 1978; Durden & Dangel, 2010; Wilcox-Herzog & Kontos, 2001). This is an important process that is left out of Rudd et al.’s (2008) work and other work on teachers’ mathematics language (Hirsch-Pasek, as cited in Quenqua, 2014).

The review of the existing empirical studies on preschool teachers’ mathematics’ language offers four key insights. One, there does seem to be a connection between the frequency of preschool teachers’ mathematics words and child outcomes in mathematics (Klibanoff et al., 2006; McCray, 2008) but there is only minimal research on this topic. Two, most of the exposure to mathematics language that children receive in early childhood classrooms is around rote counting, numeral recognition, and spatial relationships (Clements, 1999; Rudd et al., 2008) and the majority of the research on teachers’ mathematics language in the preschool classroom only examines this type of language (surrounding number and operation strands) (Klibanoff et al., 2006; McCray, 2008). Three, there is not a clear picture of how mathematics content is taught across various instructional settings. Though McCray noted some differences across settings, we need to know more about how mathematics language is used across various contexts in the preschool classroom (in terms of frequency of content strands) and its differential impact on child outcomes in mathematics. Instructional settings could play a part in the connection between teachers’ mathematics language and children’s outcomes.
And finally, as research has shown, much of preschool mathematics instruction is focused on low-level rote recall (Clements, 1999; Rudd et al., 2008). As shown, both theory and research espouse the important effects that high-level cognitively demanding teacher language can have on children’s cognitive development. Research on teachers’ mathematics talk in the elementary and middle school grades is largely focused on the role of the child in the process of teachers’ math language use (Piccolo et al., 2008; Varol & Farran, 2006; Walshaw & Anthony, 2008). Back and forth discussions are believed to be key in children’s development of math concepts, and teachers’ math talk is conceptualized through the lens of how the language aids children in constructing their own math knowledge (Piccolo et al., 2008). This is quite different from the existing literature on early childhood teachers’ math talk. In order to address this issue, and provide higher-quality mathematics instruction in preschool classrooms, we must be able to clearly define the types of preschool teachers’ mathematics language that are occurring and what elements of advanced language are missing. The conceptualization of preschool teachers’ mathematics language must be connected to past research and expanded upon.

**Rationale for the Present Study**

The existing studies on preschool teachers’ math language have built a foundation for studying the relationship between teacher math language and child outcomes in the early childhood classroom. The research shows that there are several variations in the mathematics language preschool teachers’ use. It notes variations among teachers’ language across settings and variations in what content is addressed in the language. The studies also suggest that there is a range in the complexity of language used by teachers,
even in the area of mathematics. In addition, the literature indicates that these features have some impact (or could have some impact) on children’s learning (Klibanoff et al., 2006; McCray, 2008; Rudd et al., 2008). The earlier studies have built a foundation for next steps in the research and theory.

This study will focus exclusively on preschool teachers’ mathematics language. It will look at: the type of content that teachers’ mathematics language emphasizes the mediating effects of settings on the mathematics language that is used, and the contributions of cognitive demand in teachers’ mathematics talk. The current literature shows that teachers’ mathematics talk has an impact on children’s math outcomes but we do not know the impact that these three elements have on this relationship. This study will both refine each of these three elements in regard to their use in the preschool classroom and expand on the current work by examining their connection(s) to children’s outcomes in mathematics (see Figure 3). Each of the issues addressed in this work will provide significant information regarding the conceptualization of teachers’ mathematics language and enable the field to have a better sense of what is and what should be happening in the classroom with regards to early mathematics education. It will add to both the theoretical understanding and practical application of teachers’ mathematics language use in the early childhood classroom.
Types of Math Content Emphasized in Teachers’ Language

The first key issue raised by the present work relates to the frequency of teachers’ mathematics talk in regards to various content strands, and how this relates to children’s mathematics outcomes. Klibanoff et al. (2006) argue that the frequency of teachers’ math language relates to higher outcomes in mathematics for children. McCray’s (2008) work supports this argument when only non-circle time language is considered. The research by Klibanoff et al. (2006) and McCray (2008) only look at teachers’ math language in terms of the amount of number and operation words that each teacher uses. They leave out other mathematics strands such as geometry, measurement, algebra, or data analysis. Rudd et al.’s (2008) work includes these content strands, suggesting that
some content strands are more challenging than others. Though Rudd et al.’s study examines a broad range of children (birth to age 5) it is limited in that it only looks at six classrooms and it does not connect specific content strand language to child outcomes.

In order to provide a detailed picture of teachers’ mathematics language in the preschool classroom we must examine the variations in the frequency of teachers’ mathematics language across content strands and how this relates to children’s mathematics outcomes. Research has shown that the majority of early mathematics instruction is on numeral recognition and rote counting (Clements, 1999). We don’t know if other mathematics language is equally important and if it can also effect children’s mathematics achievement. This work is important in that it provides a basis for expanding the definition of teachers’ mathematics language beyond number and operation, and illustrates the importance of using a variety of mathematics strands in the teaching of early math.

This study will examine two mathematics language groupings: utterances related to number and operations, and “other math language.” The later concept will include measurement and geometry language. These groups were selected because the literature has confirmed the connection between number and operation language and child math outcomes. This study seeks to reconfirm these findings (Klibanoff et al., 2006; McCray, 2008) and expand the work to look at other mathematics strands that could connect to children’s mathematics outcomes. Does the frequency of language in either content strand grouping impact child math outcomes? Which type of mathematical language is more important in effecting child outcomes?
In order to examine these issues the first set of questions in this study will be:
What is the frequency (and percentage) of teacher math talk across content strands (number, operation, measurement and geometry) in early childhood classrooms? Does the total frequency predict children’s mathematical gains? Does the frequency of teachers’ mathematics language in content strand group differentially predict children’s mathematical gains (number and operations versus other mathematics language)?

**Instructional Settings and their Mediating Effect on the Relationship between Teacher Language and Child Outcomes**

The second set of issues raised by the current work is where mathematics instruction is occurring in the preschool classroom and how context might mediate the relationship between teachers’ mathematics language and children’s math outcomes. Unlike the later grades, mathematics in the preschool classroom is not taught during a specific math period but it is integrated throughout the day. Since instruction occurs in such a unique way in the preschool classroom, it is difficult to talk about the learning process without thinking about the use of instructional settings. Mathematics occurs throughout the day and across a variety of instructional contexts.

The current research suggests that instructional settings could play a part in the connection between teachers’ mathematics language and children’s mathematics outcomes. Montie, Claxton and Lockhart’s (2007) work illustrates that the amount of time spent in each setting can predict children’s learning. This work, in conjunction with McCray’s (2008) work, lays the foundation for suggesting that settings might have an impact on children’s outcomes. While examining teacher math talk, McCray found that the math language used during non-circle time (a combination of free play, small group
activities, transitions, and one-on-one instruction) was significantly related to child gains in mathematics, but that the same language used during circle time was not connected to child gains. When studying teacher language and its relationship to children’s learning, instructional settings might function as an important mediator that cannot be ignored.

Examining this issue of how instructional settings moderate teachers’ language could provide important knowledge not only for the field of early childhood mathematics but also for the research on the role of these settings in instructional practice. There is little empirical research on this topic and there are some major components missing from the research. The literature on instructional settings is full of generalizations based on broad assumptions about the type of instruction that occurs in each setting and how this impacts child outcomes (Durden & Dangel, 2008; Girolametto, 2000; Kontos & Wilcox-Herzog, 1997; Massey, 2004). These generalizations give little explanation about the individual teacher-child experience. Studies that compare teacher language across settings are limited in both scope and frequency. We need to know more about how mathematics language is used in different settings in the preschool classroom, and how language use in multiple settings impacts children’s engagement with mathematical ideas and child outcomes in mathematics.

This study will examine teachers’ mathematics language in the three most common settings in preschool classrooms: whole group, small group, and free play. It will determine the frequency (and rate) of teacher math talk across three instructional settings (circle time, small group, and free play) and ask the questions: does the frequency and rate of language use in these settings differentially predict children’s mathematical gains? If the first set of results indicates that only one type of content-
strand related language is related to child outcomes, the other type of language will not be included in further analysis.

**Level of Cognitive Demand in Teachers’ Mathematics Talk**

The first two topics use the frequency of teachers’ mathematics words to examine the relationship between language and children’s outcomes, focusing specifically on the mediating effect of content strands and instructional settings. However, the literature suggests that this might not be enough to understand the complex role teachers’ language plays in the process of mathematics instruction. While the work on preschool teachers’ mathematics language focuses exclusively on the amount of teachers’ mathematical words, a broader range of literature suggests that teachers’ need to engage children in higher order thinking skills around mathematics concepts to promote learning. Both theory and research suggest that this high-level language is necessary to helping children develop deeper understanding of ideas because it requires that they help them verbalize their own ideas, problem solve, and develop complex levels of understanding (Durden & Dangel, 2008; Rudd et al., 2008; Piccolo et al., 2008; Quenqua, 2014).

Based on the NCDEL multi-state study, the National Research Council (2009) report stated:

> It is evident that mathematics, like literacy, was often taught in a manner in which teachers focused on student performance of a discrete skill or display of factual knowledge. Children were less often exposed to instruction that was conversational, interactive, and focused on understanding and problem solving. (pp. 7-11)

They go on to discuss how the use of open-ended questions in mathematics instruction is essential as such questions promote metacognitive development, executive functioning
skills, and critical academic skill development. The National Research Council (2009) report states that,

The use of open-ended questions…has the potential to increase the math talk in a classroom or in a home. Effective teachers make a greater use of open-ended questions than less effective teachers. They ask children ‘Why?’ and ‘How do you know?’ They expect children, as young as preschool, to share strategies, explain their thinking, work together to solve problems, and listen to each other. (pp. 7-17)

The abilities children gain from responding to these high-level questions lead them to be self-sustaining learners. Though current research does not show us what high-level cognitively demanding teacher mathematics language looks like in the preschool classroom, it does suggest that it could be important (Cross, Woods, & Schweingruber, 2009; Rudd et al., 2008).

The literature on broader teacher language, such as the schemas developed by Durden and Dangel (2008) and Blank, Rose and Berlin (1978), offer insight into what this type of cognitively demanding teachers’ mathematics language might look like. It shows that there could be much more to the story of preschool teachers’ mathematics language and its relationship to children’s cognitive development. To address this issue and provide higher-quality math instruction in the preschool classroom we must be able to define the types of preschool teachers’ math language that are occurring in the classroom and what elements of advanced language are missing. In order to broaden the conception of preschool teachers’ mathematics talk beyond just the frequency of words uttered by the teacher this study will ask a third set of more exploratory questions that look at how teachers’ math language engages the child in the learning process: What is
the level of cognitive demand in teacher mathematics talk in the preschool classroom and how does this relate to child outcomes in early mathematics performance?
CHAPTER III

METHODS

Study Design and Research Questions

The data for this study comes from Erikson’s Early Math Collaborative (the Collaborative). The Collaborative was launched in 2007 in response to a need for teacher professional development in early mathematics education. The goal of the Collaborative is to help teachers develop mathematics competencies, and provide quality mathematics education to children during the critical years of early schooling. As an intervention project, the Collaborative aims at teacher change in early mathematics education. This study is not designed to evaluate the effectiveness of the EMC’s work. Rather, using quantitative and qualitative methods, this study attempts to examine teachers’ mathematics language, its use in the preschool classroom and its relationship with young children’s learning. The relationship between teachers’ math language and child outcomes will be studied under three conditions: diverse mathematical content strands, different instructional settings, and the various levels of cognitive demand in the mathematics language preschool teachers’ use.

I worked as a research fellow in the EMC project during the 2008-2009 and 2009-2010 school years. With a team of researchers, I supported and led a number of data collection tasks. The present study is based on the data I collected. Three research questions guide the study:
1. What is the frequency (and percentage) of teacher math talk across content strands (number, operation, measurement and geometry) in early childhood classrooms? Does the total frequency predict children’s mathematical gains and does the frequency of teachers’ mathematics language in distinct content strand groups differentially predict children’s mathematical gains (number and operations group versus other math group)?

2. What is the frequency and rate of teacher math talk across three instructional settings (circle time, small group, and free play) and how does the frequency and rate of language use in settings differentially predict children’s mathematical gains?

3. What is the level of cognitive demand in teacher mathematics talk in the preschool classroom and how does this relate to child outcomes in early mathematics performance?

Participants

Teachers

In total, across the two years (2008-2009 and 2009-2010), 43 teachers participated in the Collaborative’s program evaluation research. Both intervention and control teachers were randomly selected from those who volunteered to participate in the program evaluation research. Since this study is not intended to evaluate the Collaborative’s professional development or teacher gains, both intervention and control teachers were included for the study and undifferentiated for the analyses. Only 31 out of the 43 research-participating teachers were selected for the present study based on the following five criteria:
1. Worked in a state prekindergarten or Head Start classroom in CPS,
2. Was a “lead” teacher in the classroom,
3. Used English as their primary language in the classroom,
4. Worked in a classroom in which English was not a second language for the majority of the students, and
5. Had been observed using the Teachers’ Math Language Observation tool for four complete cycles.

In the final analysis, data from only 27 teachers was used: three teachers were dropped due to coding errors and one teacher was dropped because no free play took place during the observation. Of the 27 teachers, 19 were intervention teachers because of their participation in the professional development program. The remaining eight teachers were from the control group and they did not participate in the Collaborative’s professional development. Among the selected teachers, 17 were observed in 2008-2009 and 10 in 2009-2010.

All 17 of the teachers observed in 2008-2009 were state Pre-K teachers in CPS. Out of the 11 intervention teachers, eight were in their first year with the EMC program and three were in their second year, that is, they started the Collaborative’s professional development in the 2007-2008 year and continued to work with the project until the end of 2008-2009 school year. The other six were from the control group, teachers who were not offered the professional development.

Data on the remaining 10 teachers was collected the following 2009-2010 school year. Of the 10 teachers, eight were intervention teachers, two were control teachers, and all of them worked in CPS Head Start preschool classrooms. Both intervention and
control teachers participated in a large intervention and research project initiated by the CPS Head Start program. Early math professional development from the Collaborative was part of this large initiative. The administrators at CPS selected intervention teachers and matched control teachers for the purpose of the program evaluation. All 10 participating teachers for this study were recruited from the Head Start’s initiative and all of them volunteered to participate in the additional research for the present study.

Because they worked in CPS, all 27 participating teachers, whether in state Pre-K or Head Start classrooms, were certified. All 27 teachers signed consents before any research was conducted, and they all received compensation at the end of the school year for their participation in the project’s research.

Children

All children who participated in the present study were recruited through their classroom teachers. As part of the Collaborative’s research, each teacher sent home child consent forms to all the parents in the class. Eight to ten children were randomly selected from the forms that were returned to the teacher. In order to participate in the study each child had to have a signed parent consent form, speak English as his/her primary language, and be at least three years and four months at the Time 1 testing point.

A total of 255 children from the 27 selected classrooms had parent consents and met the research criteria. Of these 255 children, 21 were dropped from the present study because of attrition, assignment of an IEP during the year, and time testing constraints, resulting in 234 children who were initially selected to participate in this study. Among this group of initial participants, seven children were further dropped due to insufficient data or evaluator error, thus the data from 227 children was used for the final analyses of
the study. On average 8.41 children per classroom were used for this study. The average child age at Time 1 of the testing in the fall was 52 months old (4 years and 4 months) and the average child age at Time 2 in the spring was 59 months (4 years and 11 months). In terms of gender, 124 (54.6%) children were girls and 99 (43.6%) were boys. Gender for four children was omitted at the time of data collection (1.8%).

IRB

The data selected was archival data from the Early Mathematics Collaborative Project. The Internal Review Boards at Erikson Institute and Chicago Public Schools approved the Project’s research. The confidentiality of the participants has been protected, as both teacher and child participants were given ID numbers before the data was collected. All consent procedures detailed in the Project’s IRB protocol were followed explicitly. Participating teachers were compensated for their time as part of the larger EMC Project’s research.

Instruments and Procedures

Three instruments were used in the present study: Teachers’ Mathematics Language Measure, Measure of Cognitive Demand in Mathematics Language, and Child Mathematics Assessment. As an observational tool, the first instrument was used to record the frequency of mathematics language from each teacher across different mathematics content strands and three instructional settings. The second instrument was used to analyze the data collected from the classroom observation in terms of levels of cognitive demand in teachers’ mathematics language. Finally, the Child Mathematics Assessment focused on the child math performance and gains over the school year as an outcome measure for the impact of teachers’ mathematics language. The sections below
will detail each of the three measures and report the procedures in data collection, coding, and establishing reliability.

**Teachers’ Mathematics Language Measure and Data Collection Procedures**

Adapted from Klibanoff et al.’s (2006) work, the Teacher’s Mathematics Language Measure (TMLM) is a classroom observational tool designed to record the frequency of teachers’ mathematics language across seven content areas: number, operations, measurement, geometry, spatial references, algebra and data analysis. The number and operation categories were taken directly from Klibanoff et al.’s scale (2006). From an extensive literature review, the Collaborative’s research team developed the remaining content area categories. Through the data collection process, the research team learned that while the spatial references category was too broadly defined, resulting in recording of many spatial but non-mathematical terms such as sit down and stand up, the algebra and data analysis categories were too narrow and very few frequency marks occurred. Consequently, data from only four content strands is usable for the present study: the number, operations, geometry and measurement categories (see Appendix A).

During the observation the researcher marked on the observation sheet both the frequency of mathematical language that occurred in each of the three instructional settings (whole group, small group, and free play) and the amount of minutes that the teacher spent in each of the three settings. The instructional setting was determined based on the activity that the teacher was involved in at the time the language occurred. The definition of each instructional setting was derived from a literature review (Copple & Bredekamp, 2009; Epstein, 2007). Specifically, whole group was defined as a teacher directed activity, where the focus was instructional (not transitional), and took place with
a majority of the students in the classroom. Small group was defined as a teacher
directed activity that took place with as few as two students and as many as half the
students in the class. Free play was coded when the teacher was not directing an activity
but following the students’ lead. To be coded in the free play category the majority of the
students had to be involved in free play or center activities, and the teacher could not be
doing an instructional 1-on-1 or a small group activity that was separate from free play.
Each teacher was observed on a day during the spring of either the 2008-2009 or 2009-
2010 school year. Prior to the observation each teacher was contacted via phone or email
by the Project Coordinator to set up the date and time of the observation. At this time,
during the consent procedure, and immediately prior to the observation, teachers were
informed that this observation was to look at general teaching practice.

For each observation the researchers coded the teachers’ speech beginning as
close to the start of the school day as possible. Each observation lasted for a two-hour
period. The researcher’s coded language across four 20-minute cycles, with a 10-minute
break in-between each cycle. Therefore, each language sample includes 80 total minutes
of coded teacher language. In order for the researchers to hear the teachers’ language
while not interfering with the classroom instruction, each participating teacher was asked
to wear a wireless microphone, which broadcasted a signal to the researcher. Each
teacher selected the position of the researcher prior to the start of the observation so that
they would be in the most inconspicuous place in the classroom.

After the four cycles of the language observation were completed the researcher
tallied the frequency of teacher math language for each mathematics content area and
instructional setting. They then recorded the total frequencies on corresponding summary
sheets. Once all of the teacher data was gathered a researcher entered the information from the summary sheets into SPSS. The total number of math-related utterances was calculated for each teacher across the 80-minute period. The frequency of math-related language corresponding to each content area was also calculated. Of the 27 participating teachers, one was observed for 17 minutes instead of 20 minutes in the fourth cycle. When rate (frequency over time) was considered in the analysis this teacher’s scores were adjusted to reflect the time difference.

The data on the instructional settings was entered into SPSS with the language frequencies. Total time in each of the three settings was calculated for each teacher, and average frequencies (rate) for total math language and specific math content language were calculated by dividing the math language marks in each setting by the total time spent in each setting by that particular teacher.

The researchers were trained in the TMLM via a daylong session for explanation and practice, and fieldwork with partners to practice the use of the instrument. Inter-rater reliability was established by having each researcher code the same five videos. Scores were then compared with the master codes to judge consistency. Prior to any data collection each researcher scored above 90% on the inter-rater reliability test.

**Measure of Cognitive Demand in Mathematics Language and Data Collection**

**Procedures**

No measure focusing on cognitive demand of teachers’ mathematics language in preschool settings is available at present. Measure of Cognitive Demand in Mathematics Language (MCDML) is a newly-developed tool adapted from the work of Durden and Dangel (2008) on teachers’ cognitively challenging language and the scale by Rudd et al.
(2008) on math specific language. It measures the degree of cognitive demand in the mathematics language teachers’ use in the preschool classroom. Cognitive demand is operationally defined as children’s engagement in mathematical thinking in response to teachers’ mathematical language, such as comments, prompting, or questions.

The MCDML has three levels of engagement: low, medium and high (see Table 3). The low level is isolated mathematics words and utterances that do not question or engage the child in mathematical ideas (e.g., “Here is a triangle”). The medium level encompasses questions and phrases that provoke some engagement in mathematical thinking such as rote recall or basic computations. The high category engages children in high-level cognitive thinking, such as applying knowledge and skills or explaining thinking.

Table 3. Types of Cognitive Demand in Preschool Teachers’ Mathematics Language

<table>
<thead>
<tr>
<th>Level of Engagement</th>
<th>Types of Language</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Math vocabulary/utterances with no prompting or questioning towards the child</td>
<td>● “Here is a triangle.”&lt;br&gt;● “I see you have two babies.”</td>
</tr>
<tr>
<td>Medium</td>
<td>Closed-questions or prompting that require some child response or basic recall of facts</td>
<td>● “What number is this?”&lt;br&gt;● “What is 5 + 2?”&lt;br&gt;“What comes next in the pattern?” “Which side of the triangle is longest?”</td>
</tr>
<tr>
<td>High</td>
<td>Open-ended questions that promote high-level cognitive response(s) such as asking children to explain their thinking or apply their knowledge to complete a task or answer a question</td>
<td>● “How did you know that?”&lt;br&gt;● How can you sort these objects into two groups?&lt;br&gt;● “Why…” questions, such as “Why did the tower fall down?”</td>
</tr>
</tbody>
</table>
The same language samples from the observation based on the Teachers’ Mathematics Language Measure were used for this analysis. From the 27 teachers used for the frequency analysis a subset of 15 teachers were selected for this coding procedure. Teachers were dropped because there was either no recording of language made in their classroom or there was an incomplete recording made (less than four cycles). Inter-rater reliability was determined by having two independent researchers code each of the recordings. The measure of agreement in coding was consistent, above 90%.

**Child Mathematics Assessment and Data Collection Procedures**

The child Mathematics Assessment (CMA), developed by Klein and Starkey (2001) at UC Berkeley intends to measure the mathematical learning and performance of children ages 3 to 5 in a range of content areas, including number, operation, geometry, measurement, and algebra. The CMA consists of nine sections, most of them with multiple sub-sections or questions. The total score possible on the CMA is 35 points. Taking between 15 to 25 minutes to administer, the assessment is game-like and engages children with a variety of fun manipulatives. The CMA has previously been used to measure progress over a school year, and was shown to be sensitive to significant differences among students (Klein, Starkey, & Wakeley, 1999). The instrument was chosen for the present study because of the appropriate age range and the diverse content areas covered.

All assessors received two full days of rigorous training and their assessment procedures were fully certified as reliable by the assessments’ authors. The CMA was used to assess children at two points, once at the beginning of the school year and once at the end of the school year. The time one assessments occurred in mid-September to mid-
November and the time two assessments occurred in mid-April to mid-May. The average number of days between Time 1 and Time 2 assessments was 253.2.

The assessment usually took place in a quiet location outside of the classroom. The order of child assessments was randomly selected. Data on 8 to 10 children from each class was gathered. Before beginning the process the teacher told each child that they were going to play games with the assessor. At the end of the assessment each participant received a sticker. They were then returned to their classroom. The children’s scores on each individual item and total scores were entered into SPSS for analyses. Change scores for each child were calculated for both individual scores and total scores.

**Analysis**

Three sets of research questions guide the present study. While all three questions are proposed to examine the relationship between teachers’ math language and child learning outcomes, they vary by conditions under which the math language takes place. Specifically, math content strands, instructional settings, and cognitive demands are the three different conditions examined for questions 1, 2 and 3 respectively. Specific analyses will be presented below for each set of questions

**The First Set of Research Questions**

The first set of questions includes three sub-questions. The first one is: what is the frequency (and percentage) of teacher math talk across content strands? To answer this question the frequency and percentage of teacher mathematics talk in each content strand as well as the total amount of language across all four content strands was calculated.
Descriptive comparisons were then made between the frequency and percentage of each content strand.

To answer the second question (whether the total frequency of teachers’ math language predicts children’s mathematics gains) a linear regression model was used in HLM (Hierarchical Linear Modeling). In the HLM analysis, the teachers were on level two and the children were on level 1. HLM was selected as the method of analysis because it can take into account the groupings of children nested within each teacher. This accounts for variation at both the teacher and the child levels and is more sensitive to this relationship than a linear regression model in SPSS would be.

For this question the independent variable is the frequency of mathematics language (the sum of math talk in all four strands, number, operation, measurement and geometry) and the dependent variable is the child gains in mathematics. The equation of the HLM is: (frequency of number utterances + frequency of operation utterances + frequency of measurement utterances + frequency of geometry utterances) = child’s mathematical gains (CMA score at time 2 – CMA score at time 1).

The third sub-question looks at whether type of math language in terms of content strand makes a difference in relation to child mathematics gains. Two groups of content strands, number and operation language and “other math language” (measurement and geometry language) were analyzed. The independent variables are the frequency of teachers’ mathematics language in each content strand grouping (one being number and operation math related utterances, and the other being geometry and measurement related utterances) and the dependent variable is child outcomes in mathematics. Again, a linear regression model in HLM was used for the analysis:
(frequency of number utterances and frequency of operation utterances) + (frequency of measurement utterances and frequency of geometry utterances) = child’s mathematical gains (CMA score at time 2 – CMA score at time 1)

**The Second Set of Research Questions**

The findings from question one will be used to determine what math language, in terms of frequency use, is predictive of children’s mathematics outcomes. This mathematics language will be further examined in question two: What is the frequency and rate of teacher math talk across three instructional settings (large group, small group, and free play) and how does the frequency and rate of language use in settings differentially predict children’s mathematical gains?

The second set of research questions includes two sub-questions. The first one is a descriptive question regarding the frequency and rate of teachers’ math talk across three instructional settings (large group, small group, and free play). To answer the question, both the frequency and rate of each teacher’s mathematics language in the three settings were calculated. Rate is a measure of the intensity of math language used in each setting and it was determined by frequency of language over time spent in each setting. Similar to the frequency and percentage of teachers’ math talk across different content strands, teachers’ math language among three instructional settings was compared to determine the frequency and intensity in each setting.

In order to examine if preschool teachers’ mathematics language in each setting is predictive of child’s mathematical gains two linear regression models in HLM were used. The first model tested if the frequency of teachers’ math language in each setting predicts children’s mathematics outcomes. The equation is: (frequency of language in large
group) + (frequency of language in small group) + (frequency of language in free play) = child mathematics gains (CMA score at time 2 – CMA score at time 1). In this model, the independent variable is the frequency of teachers’ math language that occurs in each instructional setting and the dependent variable is the children’s math outcomes.

The second model tests if the rate of teachers’ math language in each setting differentially predicts children’s mathematics outcomes: (rate of language in large group) + (rate of language in small group) + (rate of language in free play) = child mathematics gains (CMA score at time 2 – CMA score at time 1). In this model, the independent variable is the rate of teachers’ math language that occurs in each instructional setting and the dependent variable is the children’s math outcomes.

The Third Set of Research Questions

Again, there are two sub-questions for the third set of research questions. The first describes the level of cognitive demand in teachers’ mathematics talk in the preschool classroom. Teachers’ math language was coded into three categories (high, medium and low). The frequency of types of language occurrences and their percentages of total math-related language (e.g., frequency of high level cognitively demanding language/total coded language) were calculated to answer the questions.

The second question focuses on the level of cognitive demand in teacher mathematics talk in the preschool classroom and how this relates to child outcomes in early mathematics performance. The following linear regression model in HLM was used: (frequency of high level language) + (frequency of medium level language) + (frequency of low level language) = (CMA score at time 2 – CMA score at time 1). In
this model, the independent variable is the amount of teachers’ language at each level of complexity and the dependent variable is the children’s math outcomes.

Based on the literature it is likely that there may only be a small amount of medium- and high-level language used by teachers. If this is the case the following equation will be used: (frequency of high level language + frequency of medium level language) + (frequency of low level language) = (CMA score at time 2 – CMA score at time 1).
CHAPTER IV
RESULTS

The results provide information in regard to each of the three major research areas: the type of content that teachers’ mathematics language emphasizes, the mediating effects of instructional settings on the mathematics language that teachers use, and the contribution of cognitive demand in teachers’ mathematics language. The relationship between each of these three areas and children’s outcomes in mathematics will also be detailed in this chapter. For the analysis of math content in teachers’ language and language use in instructional settings, the starting sample group was 27 teachers and 227 students. A smaller sub-sample of 15 teachers (not 27 teachers) was used for the analysis regarding the level of cognitive demand in teachers’ mathematics talk. It is important to keep this sample size in mind when reviewing the results.

Teachers’ Mathematics Language: Math Content

The Teacher’s Mathematics Language Measure (TMLM) gathered data on the frequency of teachers’ mathematics language utterances across four different mathematics content strands (number, operations, geometry and measurement) and in three unique settings (large group, small group, and free play). Initial analysis showed that two out of the 27 teachers were outliers in the geometry category of teachers’ language use. Outliers were determined by identifying values that were extreme variables (outside of the outer fence). The equation used to identify outliers is: Extreme Outliers > Q3 +3 (IQR). “Q3” represents the third quartile of the data and “IQR” is the
interquartile range (quartile 3-quartile 1) for the data set. The value of the outer fence was $35 + 3 \times (30) = 125$. As you can see from table 4 the two extreme outliers in the geometry category were 141 and 214. Both of them are greater than 125. In Figure 4, asterisks represent these values. These teachers were subsequently dropped from the descriptive and comparative analysis relating to content strands.

**Types of Content Strands Emphasized in Teachers’ Math Language**

The analysis on the frequency of teachers’ mathematics language across the four content strands (see Table 4, Figure 4, and Table 5) illustrates that over half of the mathematics language teachers used was related to the content strand of number (54.78%). Utterances related to measurement came next at 31.42%, followed by utterances related to geometry at 10.36%, and finally the utterances related to operations occurred the least at 3.44%. Interestingly, 11 teachers did not use any language related to the operations strand. The range was 72-393 utterances of mathematics language during the collection time period of 80 minutes. The mean amount of total language teachers used related to the four content strands was 216.52 utterances with a standard deviation of 100.60. The two-hour period (80 minutes of coding) was an important extension of current work related to teachers’ language. It was an elongated period of coding compared with Klibanoff et al. (2006) who observed for 2.5 to 3 hours and coded for one hour, and McCray (2008) who coded for one hour.
Table 4. Frequency and Percentage Comparisons of Teacher Math Talk across Content Strands (including two outliers)

<table>
<thead>
<tr>
<th>Teacher ID</th>
<th>Content Strands</th>
<th>Total Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number Freq.</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>249 75.00</td>
<td>3 0.90</td>
</tr>
<tr>
<td>2</td>
<td>97 55.75</td>
<td>19 10.92</td>
</tr>
<tr>
<td>3</td>
<td>154 61.11</td>
<td>0 0</td>
</tr>
<tr>
<td>4</td>
<td>142 64.84</td>
<td>0 0</td>
</tr>
<tr>
<td>5</td>
<td>67 69.79</td>
<td>0 0</td>
</tr>
<tr>
<td>6</td>
<td>193 77.20</td>
<td>2 0.80</td>
</tr>
<tr>
<td>7</td>
<td>179 58.50</td>
<td>2 0.65</td>
</tr>
<tr>
<td>8</td>
<td>36 50.00</td>
<td>0 0</td>
</tr>
<tr>
<td>9</td>
<td>58 36.94</td>
<td>0 0</td>
</tr>
<tr>
<td>10</td>
<td>122 55.96</td>
<td>4 1.84</td>
</tr>
<tr>
<td>11</td>
<td>39 37.14</td>
<td>0 0</td>
</tr>
<tr>
<td>12</td>
<td>151 76.65</td>
<td>11 5.58</td>
</tr>
<tr>
<td>13</td>
<td>204 62.01</td>
<td>19 5.77</td>
</tr>
<tr>
<td>14</td>
<td>112 57.43</td>
<td>25 12.82</td>
</tr>
<tr>
<td>15</td>
<td>99 24.88</td>
<td>19 4.77</td>
</tr>
<tr>
<td>16</td>
<td>81 45.25</td>
<td>0 0</td>
</tr>
<tr>
<td>17</td>
<td>37 33.33</td>
<td>6 5.41</td>
</tr>
<tr>
<td>18</td>
<td>62 38.75</td>
<td>0 0</td>
</tr>
<tr>
<td>19</td>
<td>293 57.45</td>
<td>22 4.31</td>
</tr>
<tr>
<td>20</td>
<td>151 59.92</td>
<td>30 11.90</td>
</tr>
<tr>
<td>21</td>
<td>79 34.95</td>
<td>36 15.93</td>
</tr>
<tr>
<td>22</td>
<td>103 42.74</td>
<td>2 0.83</td>
</tr>
<tr>
<td>23</td>
<td>109 61.24</td>
<td>0 0</td>
</tr>
<tr>
<td>24</td>
<td>24 22.64</td>
<td>0 0</td>
</tr>
<tr>
<td>25</td>
<td>169 43.00</td>
<td>5 1.27</td>
</tr>
<tr>
<td>26</td>
<td>144 32.00</td>
<td>2 0.45</td>
</tr>
<tr>
<td>27</td>
<td>54 34.84</td>
<td>0 0</td>
</tr>
</tbody>
</table>
Table 4 (continued)

<table>
<thead>
<tr>
<th>Content Strand</th>
<th>Total</th>
<th>51.24</th>
<th>207</th>
<th>3.31</th>
<th>1930</th>
<th>30.82</th>
<th>916</th>
<th>14.63</th>
<th>6261</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Outliers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3208</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without Outliers</td>
<td>2965</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Freq. means total frequency of math utterances that refers to that content strand during two hours. % indicates percentage of math utterances that fall in each content strand area divided by total frequency of math utterances.

*The identified outliers in the data.

Figure 4. Analysis of Outliers in Geometry Strand

Note. Outliers indicated by asterisks (*). They were dropped in further analysis involving content strands. Therefore they are not reflected in the below tables and figures.
Figure 5. Teachers’ Language Use: Math Content Strands

Table 5. Mean and Standard Deviation of the Frequency of Teachers’ Mathematics Language across Content Strands

<table>
<thead>
<tr>
<th>Content Strands</th>
<th>Number</th>
<th>Operations</th>
<th>Measurement</th>
<th>Geometry</th>
<th>Total Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>118.81</td>
<td>7.44</td>
<td>68.04</td>
<td>22.44</td>
<td>216.52</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>69.72</td>
<td>10.92</td>
<td>29.15</td>
<td>22.18</td>
<td>100.60</td>
</tr>
<tr>
<td>Range</td>
<td>24-293</td>
<td>0-30</td>
<td>29-139</td>
<td>1-85</td>
<td>1-293</td>
</tr>
</tbody>
</table>

Relationship between the Frequency and Type of Teachers’ Mathematics Language, and Child Outcomes in Mathematics

The following question was posed in an effort to examine this relationship: Does the total frequency predict children’s mathematical gains and does the frequency of teachers’ mathematics language in content strand group differentially predict children’s mathematical gains (number and operations group versus other math group)? Previous research on the connection between the frequency of teachers’ mathematics language and
child outcomes analyzed one type of language, combined number and operation utterances. The above question builds on this work in two ways: first, it looks at whether broadening the construct of “teachers’ mathematics language” to include four diverse strands (number, operations, measurement and geometry) will connect to children’s mathematics outcomes. Second, it goes even further, to see if which grouping of language: “number and operations” or “other mathematics language” connects to child math outcomes. Which group of language has a more powerful impact on increasing child math outcomes?

A linear regression model was used in 2-level Hierarchical Linear Modeling (HLM) to analyze whether the frequency of teachers’ total mathematics language (combined number, operations, measurement and geometry language) predicts children’s mathematics gains. The independent variable was the frequency of total mathematics language (the sum of the frequency of the language across all four content strands) and the dependent variable was child outcomes in mathematics. The child outcome was measured based on the child’s change score from time 1 to time 2 using the CMA. Twenty-five teachers and 208 children were used for this analysis.

The equation is: (frequency of teachers’ number, operation, measurement, and geometry language) = child mathematics gains (CMA score at time 2 – CMA score at time 1).

The results indicate that the frequency of total mathematical utterances combining all four strands was not significantly predictive of children’s mathematics gains (r=0.044; p=0.134).
Next, two groupings of teachers’ mathematics language were used to see if the two groups of “number and operations” and “other math language” differentially predict child mathematics outcomes. These groupings were selected because previous research showed that “number and operations” language does predict child mathematics outcomes. The choice was made to not to use number, operations, geometry, and measurement as separate constructs linked to child outcomes because of the desire to re-create and connect with previous work, and also because of the variance that exists in the amount of language that was collected in each group. Operations language only represented 3% of the total language. This variance as compared to the other content strands would make it difficult to use as a comparison variable if all four strands were entered separately in the HLM equation. The existing literature substantiates the argument for combining number and operations strands into one construct when predicting child mathematics outcomes (Klibanoff et al., 2006). Operations language is a valuable variable, and can be combined with number language since there is a theoretical connection between both groups (i.e., they both represent language related to number/quantity or manipulation of number/quantities).

To examine whether the frequency of teachers’ mathematics language when broken into the two constructs (“combined number and operations” and “other math language”) is predictive of child outcomes another linear regression in HLM was preformed (see Table 6).

The equation is: (frequency of number and operations language) + (frequency of other math language) = child mathematics gains (CMA score at time 2 – CMA score at time 1).
The frequency of teachers’ combined number and operations language was a significant predictor of children’s mathematics gains ($r=0.013$, $p=0.022$). “Other math language” was not significantly predictive of child math outcomes. Since teacher language related to combined number and operations was a significant predictor of children’s math outcomes it will be used in the analysis moving forward.

Table 6. Results of 2-Level HLM Model to Predict Children’s Gains on CMA Teachers’ Mathematics Language, Two Groups (“number and operations language” and “other mathematics language”) as Predictors

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Intercept 1, $\pi_0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept 2, $\beta_{oo}$</td>
<td>6.149</td>
<td>0.731</td>
<td>8.407</td>
<td>22</td>
<td>0.000</td>
</tr>
<tr>
<td>VARIABLE, Number and Operations</td>
<td>0.013</td>
<td>0.005</td>
<td>2.473</td>
<td>22</td>
<td>0.022*</td>
</tr>
<tr>
<td>VARIABLE, Measurement and Geometry</td>
<td>-0.009</td>
<td>0.007</td>
<td>-1.247</td>
<td>22</td>
<td>0.226</td>
</tr>
</tbody>
</table>

*p<0.05

*Note. Final estimation of variance components: p-value is 0.084.

Teachers’ Mathematics Language: Instructional Settings

Analyses with regard to instructional settings, attempts to answer two questions.

First, where does teachers’ mathematics language occur in the preschool classroom?

Second, do instructional settings serve as a mediating factor of the relationship between the frequency of teachers’ mathematics language and children’s outcomes in mathematics?
Frequency and Rate of Teachers’ Math Language in Instructional Settings

To start, the frequency and rate of teacher mathematics language (combined number and operations utterances) in the three settings of large group, small group, and free play is detailed (see Table 7). Means and standard deviations of teachers’ mathematics language used in each instructional setting are reported in Table 8.

Frequency is the total number of math language utterances that occurred in each setting. Rate is a measure of the intensity of math language used in each setting. Rate was determined by frequency of language divided by the minutes used in each setting. It is important to note that the two teachers who were identified as outliers in the analysis of content language were included in this sample. They were identified as outliers because of their use of geometry related language, not because of their number and operations utterances. Therefore they were kept for this analysis. The total number of teachers used was 27.
Table 7. Frequency and Rate of Teacher Math Talk (number and operations language) across Instructional Settings

| Teacher ID | Large Group | | | Small group | | | Free play | | | Total | | | Freq | Time (mins) | Rate | Freq | Time (mins) | Rate | Freq | Time (mins) | Rate | Freq | Time (mins) | Rate |
|------------|-------------|------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|-------------|----------------|
| 1          | 7           | 11         | 0.64           | 157         | 32             | 4.91         | 29             | 6           | 4.83           | 193         |                 |             |                 |             |                 |             |                 |             |                 |
| 2          | 19          | 27         | 0.70           | 89          | 27             | 3.30         | 4              | 18          | 0.22           | 112         |                 |             |                 |             |                 |             |                 |             |                 |
| 3          | 69          | 41         | 1.68           | 64          | 25             | 2.56         | 3              | 3           | 1.00           | 136         |                 |             |                 |             |                 |             |                 |             |                 |
| 4          | 88          | 46         | 1.91           | 9           | 14             | 0.64         | 11             | 4           | 2.75           | 108         |                 |             |                 |             |                 |             |                 |             |                 |
| 5          | 9           | 6          | 1.50           | 8           | 21             | 0.38         | 1              | 2           | 0.50           | 18          |                 |             |                 |             |                 |             |                 |             |                 |
| 6          | 145         | 50         | 2.90           | 25          | 9              | 2.78         | 20             | 11          | 1.82           | 190         |                 |             |                 |             |                 |             |                 |             |                 |
| 7          | 122         | 33         | 3.70           | 45          | 31             | 1.45         | 10             | 7           | 1.43           | 177         |                 |             |                 |             |                 |             |                 |             |                 |
| 8          | 6           | 9          | 0.67           | 8           | 35             | 0.23         | 3              | 9           | 0.33           | 17          |                 |             |                 |             |                 |             |                 |             |                 |
| 9          | 43          | 52         | 0.83           | 4           | 3              | 1.33         | 8              | 17          | 0.47           | 55          |                 |             |                 |             |                 |             |                 |             |                 |
| 10         | 84          | 52         | 1.62           | 34          | 16             | 2.13         | 3              | 5           | 0.60           | 121         |                 |             |                 |             |                 |             |                 |             |                 |
| 11         | 24          | 26         | 0.92           | 12          | 48             | 0.25         | 1              | 2           | 0.50           | 37          |                 |             |                 |             |                 |             |                 |             |                 |
| 12         | 78          | 33         | 2.36           | 66          | 25             | 2.64         | 18             | 21          | 0.86           | 162         |                 |             |                 |             |                 |             |                 |             |                 |
| 13         | 123         | 20         | 6.15           | 83          | 40             | 2.08         | 17             | 20          | 0.85           | 223         |                 |             |                 |             |                 |             |                 |             |                 |
| 14         | 38          | 25         | 1.52           | 94          | 38             | 2.47         | 0              | 5           | 0.00           | 132         |                 |             |                 |             |                 |             |                 |             |                 |
| 15         | 90          | 38         | 2.37           | 1           | 13             | 0.08         | 24             | 22          | 1.09           | 115         |                 |             |                 |             |                 |             |                 |             |                 |
| 16         | 31          | 37         | 0.84           | 14          | 12             | 1.17         | 26             | 20          | 1.30           | 71          |                 |             |                 |             |                 |             |                 |             |                 |
| 17         | 9           | 28         | 0.32           | 15          | 27             | 0.56         | 19             | 20          | 0.95           | 43          |                 |             |                 |             |                 |             |                 |             |                 |
| 18         | 11          | 19         | 0.58           | 44          | 16             | 2.75         | 6              | 33          | 0.18           | 61          |                 |             |                 |             |                 |             |                 |             |                 |
| 19         | 202         | 24         | 8.42           | 74          | 10             | 7.40         | 39             | 40          | 0.98           | 315         |                 |             |                 |             |                 |             |                 |             |                 |
| 20         | 49          | 25         | 1.96           | 129         | 42             | 3.07         | 2              | 6           | 0.33           | 180         |                 |             |                 |             |                 |             |                 |             |                 |
| 21         | 57          | 30         | 1.90           | 12          | 14             | 0.86         | 34             | 25          | 1.36           | 103         |                 |             |                 |             |                 |             |                 |             |                 |
| 22         | 80          | 30         | 2.67           | 6           | 16             | 0.38         | 1              | 8           | 0.13           | 87          |                 |             |                 |             |                 |             |                 |             |                 |
| 23         | 37          | 23         | 1.61           | 39          | 4              | 9.75         | 9              | 34          | 0.26           | 85          |                 |             |                 |             |                 |             |                 |             |                 |
| 24         | 9           | 17         | 0.53           | 4           | 20             | 0.20         | 11             | 40          | 0.28           | 24          |                 |             |                 |             |                 |             |                 |             |                 |
| 25         | 82          | 28         | 2.93           | 5           | 15             | 0.33         | 16             | 25          | 0.64           | 103         |                 |             |                 |             |                 |             |                 |             |                 |
| 26         | 102         | 31         | 3.29           | 2           | 7              | 0.29         | 13             | 30          | 0.43           | 117         |                 |             |                 |             |                 |             |                 |             |                 |
| 27         | 16          | 19         | 0.84           | 9           | 37             | 0.24         | 29             | 22          | 1.32           | 54          |                 |             |                 |             |                 |             |                 |             |                 |

Total 1630 780 2.09* 1052 597 1.76 357 455 0.78 3039

Notes. The asterisk (*) indicates that this is a calculated mean score of the totals in each category. Language in other settings such as mealtime and transitions are not included in this table.
Table 8. Means and Standard Deviations of the Frequency and Rate of Teachers’ Mathematics Language across Instructional Settings

<table>
<thead>
<tr>
<th>Instructional Settings</th>
<th>Large Group</th>
<th>Instructional Settings</th>
<th>Small Group</th>
<th>Instructional Settings</th>
<th>Free Play</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Rate (per minute)</td>
<td>Frequency</td>
<td>Rate (per minute)</td>
<td>Frequency</td>
</tr>
<tr>
<td>Mean</td>
<td>60.37</td>
<td>2.09</td>
<td>38.96</td>
<td>1.76</td>
<td>13.22</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>49.47</td>
<td>1.79</td>
<td>42.17</td>
<td>2.29</td>
<td>11.20</td>
</tr>
<tr>
<td>Range</td>
<td>7-202</td>
<td>0.32-8.42</td>
<td>1-157</td>
<td>0.08-7.40</td>
<td>1-39</td>
</tr>
</tbody>
</table>

Teachers used more number and operations language during large group than they did in the other two settings. Teachers’ number and operations language during large group accounted for 53.64% of the total number and operations language. Comparatively 34.62% occurred during small group time and 11.74% during free play (see Figure 6). The time spent in large group was also greater, as was the rate of language used. When averages were taken there was less time spent in free play than in the other settings. The mean time spent in large group was 28.89 minutes, small group was 22.11 minutes, and free play was 16.85 minutes.

Figure 6. Frequency of Teachers’ Mathematics Language in Three Instructional Settings
The average rate of language in large group was the highest at 2.09 combined number and operations utterances per minute, compared to 1.76 utterances/minute in small group and 0.78 utterances/minute during free play. The intensity of the number and operations language is the greatest during large group (see Figure 7).

![Bar chart showing rate of mathematics language in three instructional settings](chart.png)

**Figure 7.** Rate of Mathematics Language in Three Instructional Settings (frequency of number and operations utterances divided by time spent in each setting)

**Teachers’ Mathematics Language in Each Setting and its Relationship to Child Math Outcomes**

In order to examine if preschool teachers’ mathematics language in each setting is predictive of child mathematical gains two linear regression models in HLM were used. The first model tested if the frequency of teachers’ math language in each setting is predictive of children’s mathematics outcomes. In this model the independent variable is the frequency of teachers’ math language that occurs in each instructional setting and the dependent variable is the children’s math outcomes.
The equation is: 

\[
(frequency \text{ of language in large group}) + (frequency \text{ of language in small group}) + (frequency \text{ of language in free play}) = \text{child mathematics gains (CMA score at time 2 – CMA score at time 1)}.
\]

The analysis showed several important findings (see Table 9). The frequency of teachers’ number and operations language in small group was highly significantly predictive of child math gains \((r=0.023, p=0.001)\). The frequency of this language in large group was not significantly predictive. Interestingly, the frequency of teachers’ number and operations language in free play was significantly related but in a negative direction \((r=-0.056, p=0.05)\).

**Table 9. Results of 2-Level HLM Model to Predict Children’s Gains on CMA, Teachers’ Mathematics Language in Each Setting as a Predictor**

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>Df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Intercept1, (\pi_0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept 2, (\beta_{00})</td>
<td>5.859</td>
<td>0.708</td>
<td>8.277</td>
<td>22</td>
<td>0.000</td>
</tr>
<tr>
<td>VARIABLE, frequency of language in large group</td>
<td>0.008</td>
<td>0.007</td>
<td>1.127</td>
<td>22</td>
<td>0.272</td>
</tr>
<tr>
<td>VARIABLE, frequency of language in small group</td>
<td>0.0223</td>
<td>0.006</td>
<td>3.727</td>
<td>22</td>
<td>0.001*</td>
</tr>
<tr>
<td>VARIABLE, frequency of language in free play</td>
<td>-0.056</td>
<td>0.0270</td>
<td>-2.081</td>
<td>22</td>
<td>0.049*</td>
</tr>
</tbody>
</table>

*p<0.05

Note. The final estimation of variance components: p-value is 0.191.

The next equation tested if the rate of teachers’ math language in each setting predicts children’s mathematics outcomes. In this model, the independent variable is the rate of teachers’ math language that occurs in each instructional setting and the dependent variable is the children’s math outcomes. The equation is: 

\[
\text{rate of language in large group} + \text{rate of language in small group} + \text{rate of language in free play} = \text{child mathematics gains (CMA score at time 2 – CMA score at time 1)}.
\]
group) + (rate of language in small group) + (rate of language in free play) = child mathematics gains (CMA score at time 2 – CMA score at time 1).

The rate of teachers’ mathematics language (intensity of number and operations language) was not significantly predictive of child mathematics outcomes in any of the three settings (see Table 10). The final estimation of variance components indicates that more variance needs to be explained beyond these factors since p<0.05 (p= 0.023). Since the frequency of teachers’ math language in small group was highly significantly predictive of child math outcomes, yet the rate of the language in this setting was not predictive, an HLM linear regression was run to see if the relationship between the time spent in each setting was predictive of child math outcomes. The equation is: (time in large group) + (time in small group) + (time in free play) = child mathematics gains (CMA score at time 2 – CMA score at time 1).

### Table 10. Results of 2-Level HLM Model to Predict Children’s Gains on CMA, Teachers’ Rate (intensity) of Mathematics Language in Each Setting as a Predictor

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>Df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept1, ( \pi )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept 2, ( \beta )</td>
<td>6.254</td>
<td>0.681</td>
<td>9.189</td>
<td>23</td>
<td>0.000</td>
</tr>
<tr>
<td>VARIABLE, rate of language in large group</td>
<td>-0.016</td>
<td>0.161</td>
<td>-0.098</td>
<td>23</td>
<td>0.923</td>
</tr>
<tr>
<td>VARIABLE, rate of language in small group</td>
<td>0.224</td>
<td>0.154</td>
<td>1.448</td>
<td>23</td>
<td>0.161</td>
</tr>
<tr>
<td>VARIABLE, rate of language in free play</td>
<td>0.112</td>
<td>0.224</td>
<td>0.502</td>
<td>23</td>
<td>0.620</td>
</tr>
</tbody>
</table>

*Note. The final estimation of variance components: p-value is 0.023.*
The amount of time spent in both large group (p=0.927) and small group (p=0.615) was not significantly predictive of children’s math gains. Surprisingly, time spent in free play was negatively predictive of children’s math gains (r=−0.08, p=0.024). On average there was significantly less time spent in free play than in the other settings. The average time spent in free play was only 16.85 minutes.

**Additional Analyses**

Since the frequency of teachers’ number and operations language in small group was significantly predictive of children’s mathematics outcomes, two additional analyses were run to gather more information about the mediating effects of the small group setting on this relationship. When language across all four content strands was combined (number, operations, measurement and geometry), the total frequency of language in small group was significantly related to child math gains (r=0.019, p=0.004). However, the frequency of total math language in large group and free play was not significantly related to child outcomes in math.

Another interesting finding appeared when the rate of number language in small group and the rate of operations language in small group were tested as separate constructs to see if either of them was predictive of child math gains independently. The rate of operations utterances in small group was highly significantly and positively predictive of child math gains (r=2.76, p=0.003). The rate of number utterances in small group alone was not significantly predictive of child outcomes in math and the operations utterances in both large group and free play were also not predictive.
Teachers’ Mathematics Language: Level of Cognitive Demand

The final area of research examines the type of mathematical language that teachers are using in terms of the cognitive demand. The question is: What is the level of cognitive demand in teacher mathematics talk in the preschool classroom and how does this relate to child outcomes in early mathematics performance? Fifteen teachers and 125 children were used for this sample. This smaller sample size is due to the recordings that were made of teacher mathematics language.

Level of Cognitive Demand in Teachers’ Mathematics Talk: Frequency and Relationship to Child Outcomes in Mathematics

To start, teachers’ math language was coded into three categories (high, medium and low cognitively demanding language). Language across all four strands was collected. The total coded language for all strands was 2264 (see Table 11). A breakdown of teachers’ math language by content strand and cognitive demand is illustrated in Figure 8. Of all the coded language (across four strands) 72.53% was low-level, 26.19% was medium-level, and 1.28% was high level.

Table 11. Levels of Cognitive Demand in Teacher Math Talk: Frequency and Percentage across Content Strand

<table>
<thead>
<tr>
<th>Content Strands</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Total Coded Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>964 (72%)</td>
<td>371 (27%)</td>
<td>10 (1%)</td>
<td>1345</td>
</tr>
<tr>
<td>Operations</td>
<td>41 (33%)</td>
<td>77 (62%)</td>
<td>7 (5%)</td>
<td>125</td>
</tr>
<tr>
<td>Measurement</td>
<td>332 (88%)</td>
<td>37 (10%)</td>
<td>7 (2%)</td>
<td>376</td>
</tr>
<tr>
<td>Geometry</td>
<td>305 (73%)</td>
<td>108 (26%)</td>
<td>5 (1%)</td>
<td>418</td>
</tr>
<tr>
<td>Totals</td>
<td>1642 (73%)</td>
<td>593 (26%)</td>
<td>29 (1%)</td>
<td>2264</td>
</tr>
<tr>
<td>Percentage</td>
<td>72.53%</td>
<td>26.19%</td>
<td>1.28%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Though language was collected based on content strands, based on the above findings it made sense to divide it into two major categories “combined number and operations language” and “other language” which includes geometry and measurement. Due to earlier findings this first type of language is of significant interest. The purpose of this analysis was take a more in-depth look at the combined number and operations language that was occurring, since this was connected to children’s mathematics gains in early analysis.

“Combined number and operations language” was 64.93% of the total coded language and “other language” was 35.07% (see Table 12). Low-level “combined number and operations language” was 44.39% of the total coded language. When the level of cognitive demand for just teachers’ number and operations language is examined, only a very small amount of high-level language across all fifteen teachers was observed: 17 utterances. Low-level number and operations language compiles 68.37% of the total number and operations language, 30.48% is medium level, and 1.15% is high level. Clearly far more low-level cognitively demanding language is occurring (see Figure 9).
Table 12. Levels of Cognitive Demand in Teacher Math Talk: Frequency and Percentage in Two Categories

<table>
<thead>
<tr>
<th>Teacher ID</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Total Coded Language</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Num and Op</td>
<td>Other</td>
<td>Num and Op</td>
<td>Other</td>
</tr>
<tr>
<td>1</td>
<td>54</td>
<td>181</td>
<td>37</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>147</td>
<td>37</td>
<td>52</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>127</td>
<td>23</td>
<td>36</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>86</td>
<td>7</td>
<td>76</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>17</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>54</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>9</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>92</td>
<td>27</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>39</td>
<td>67</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>81</td>
<td>43</td>
<td>54</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>33</td>
<td>33</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>64</td>
<td>27</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>13</td>
<td>67</td>
<td>57</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>36</td>
<td>26</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>45</td>
<td>29</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>1005</td>
<td>637</td>
<td>448</td>
<td>145</td>
</tr>
<tr>
<td>Percentage</td>
<td>44.39%</td>
<td>28.14%</td>
<td>19.79%</td>
<td>6.40%</td>
</tr>
</tbody>
</table>

| Combined Totals | 1642 | 593 | 29 | 2264 |

Note. “Percentage” indicates each category total divided by total coded language.

Figure 9. High, Medium, and Low Level Teacher Language (number and operations strands)
Level of Cognitive Demand in Teachers’ Math Talk: Relationship to Child Math Outcomes

Next, the level of cognitive demand in teacher math talk (low, medium and high) and how this relates to child outcomes in early math was investigated. Fifteen teachers and 125 students were used for this analysis. In the model just teachers’ language related to number and operations was examined. The independent variable was the teachers’ language (number and operations) and the dependent variable was the children’s math outcomes. The linear regression equation in HLM was: (frequency of high level language) + (frequency of medium level language) + (frequency of low level language) = (CMA score at time 2 – CMA score at time 1).

The findings from the model are shown in Table 13. Since there was only a small amount of medium and high-level language used by teachers the chance of having significant findings was remote. Final estimation of fixed effects was used in HLM since the level two variable only had a sample size of 15 teachers. This is not considered to be a large sample size statistically. No significant findings were found. Though not significant, the low-level language (which represented the largest amount of language in both models) had a negative coefficient.
Table 13. Results of 2-Level HLM Model to Predict Children’s Gains on CMA, Teachers’ High, Medium and Low Level Number and Operations Language as a Predictor

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Intercept, $\pi_0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept 2, $\beta_{oo}$</td>
<td>6.675</td>
<td>1.404</td>
<td>4.754</td>
<td>11</td>
<td>0.000</td>
</tr>
<tr>
<td>VARIABLE, low level language</td>
<td>-0.004</td>
<td>0.030</td>
<td>-0.150</td>
<td>11</td>
<td>0.884</td>
</tr>
<tr>
<td>VARIABLE, medium level language</td>
<td>0.028</td>
<td>0.033</td>
<td>0.848</td>
<td>11</td>
<td>0.415</td>
</tr>
<tr>
<td>VARIABLE, high level language</td>
<td>-0.203</td>
<td>0.482</td>
<td>-0.420</td>
<td>11</td>
<td>0.682</td>
</tr>
</tbody>
</table>

Note. The final estimation of variance components: p-value is 0.159. Final estimation of fixed effects.

A weighted analysis was completed for two reasons: there was very little high and medium level language found and it can be argued that this language (though used less often) might have a more powerful effect then other language since it places a higher cognitive demand on the child. By performing a weighted analysis, more power is given to the medium and high-level language. This increases the power of the comparison that can be made between the constructs by adjusting the contribution of the medium and high-level language. For the weighted analysis 15 teachers and 125 children were used.

Low-level language was given one point, medium-level language was given two points, and high-level language was given three points. High and medium level language was combined. The mean number of high/medium-level number and operations utterances was 31 with a standard deviation of 21.83. The mean number of low-level number and operations utterances was 66.33 with a standard deviation of 35.14. High/medium language and low level language were used in a linear regression HLM equation to examine their relationship with children’s math outcomes. A model was used
that only included language related to number and operations (results in Table 14). The equation was: 

\[
(frequency\ of\ high\ level\ language + frequency\ of\ medium\ level\ language) + (frequency\ of\ low\ level\ language) = (CMA\ score\ at\ time\ 2 – CMA\ score\ at\ time\ 1).
\]

In the weighted analyses, no significance was found for the relationship between the cognitive demand in teachers’ mathematics language and children’s outcomes in mathematics. However, the data did show that the coefficient representing teachers’ low-level language was negative and the coefficient representing medium/high-level language was positive.

Table 14. Results of 2-Level Weighted HLM Model to Predict Children’s Gains on CMA, Teachers’ High/Medium (combined) and Low Level Number and Operations Language as a Predictor

<table>
<thead>
<tr>
<th>12</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Intercept, ( \pi_0 )</td>
<td>Intercept 2, ( \beta_{100} )</td>
<td>7.081</td>
<td>1.082</td>
<td>6.546</td>
<td>12</td>
</tr>
<tr>
<td>VARIABLE, low level language</td>
<td>-0.017</td>
<td>0.020</td>
<td>-0.851</td>
<td>12</td>
<td>0.412</td>
</tr>
<tr>
<td>VARIABLE, med/high level language</td>
<td>0.016</td>
<td>0.016</td>
<td>1.022</td>
<td>12</td>
<td>0.327</td>
</tr>
</tbody>
</table>

Note. The final estimation of variance components: p-value is 0.209. Final estimation of fixed effects.
CHAPTER V
DISCUSSION

The current literature on teachers’ mathematics language in the preschool classroom provides a starting point for the three major areas addressed in this study. The research has a simplistic view of the definition of “teachers’ mathematics language.” It looks at the frequency of number and operation utterances. There is no extensive work on teachers’ mathematics language that examines other content strands or the type of math language that is occurring in the preschool classroom. The current literature does not shed light on many issues concerning the possible impact of context: where teachers’ use mathematics language in the classroom. By advancing the work in definition, context, and by looking at the cognitive demand that teachers’ mathematical language places on the child, this study offers clear next steps in the research.

The Teachers’ Mathematics Language Measure (TMLM) gathered data on the frequency of teachers’ math utterances across four content strands and three instructional settings. The data collected showed that over half of the math language that teachers’ used was related to number and the least amount of language was related to operations. In agreement with earlier research the combined construct of “number and operations” had a significant connection to children’s outcomes in mathematics across the preschool year (Klibanoff et al., 2006; McCray, 2008). This connection is important because of the known short and long-term impact of children’s mathematics outcomes during these early years (Copley, 2010; Duncan et al., 2007; National Research Council, 2009).
The TMLM also showed that the majority of teachers’ math utterances (related to number and operations) occurred during large group time. One of the most interesting and exciting findings is that the more mathematics language related to number and operations that teachers’ used in small group, the higher the gains the children had in mathematics, though rate of math language was not predictive. These findings suggest that teachers explore more mathematics concepts during large group time, but that they also create important small group opportunities to explore mathematical concepts. This aligns with McCray’s (2008) work that found that teachers’ number and operations language in non-circle time activities was significantly connected to child outcomes.

The final area of research looks at the teacher-child interaction and the cognitive demand that teachers’ mathematics language places on the child. Though this study still examines only teachers’ mathematics language, this is a much needed addition to the research in that it expands the conceptualization of “teacher math talk” to include the complexity of the words and phrases used by teachers. It looks at how this language attempts to engage the child in the discussion of mathematical ideas. The set of questions regarding the cognitive demand of teachers’ language attempts to blend the work that exists on the frequency of teachers’ mathematics words (Klibanoff et al., 2006; McCray, 2008) and the other work on general (meaning non-content specific) language in the classroom (Durden & Dangel, 2008; Wilcox-Herzog & Kontos, 2001).

The current work illustrates why interactions and the impact of “language” on children’s learning cannot be summarized by looking exclusively at the frequency with which teachers’ use math words. The study shows that 68.37% of the combined number and operations language that teachers’ used was low-level while only 1.15% was high-
level. Due to sample size, there was little chance of finding significance when this language was connected to child math outcomes in the linear regression model. When the language was weighted the low-level language indicated a negative connection with child outcomes and the medium/high level language indicated a positive directionality. However, this was not at the level of significance. The case examples provide important information about the type of language that is occurring in the interactions between individual teachers’ and students around mathematical concepts. These qualitative examples provide some of the best evidence to date in exploring the story of teachers’ mathematics language.

Overall, the findings of this study indicate the importance of teachers’ mathematics language in the classroom, especially with regard to number and operations, and its impact on children’s mathematics outcomes. They also offer valuable insight into the role instructional settings might have on this relationship and the potential of investigating “language” by exploring the interaction between the teacher and the child. This chapter provides a detailed description of how this work supports, expands, and challenges the current work on teachers’ mathematics language. The study offers insights regarding the current literature and the elements represented in Figure 10: the relationship between the child, teacher, instructional settings, and the role of teachers’ mathematics language. These connections will be discussed and limitations of this study will also be given.
The first subset of questions looks at the frequency and rate of mathematics language across content strands: What is the frequency (and percentage) of teacher math talk across content strands (number, operation, measurement and geometry) in early childhood classrooms? Does the total frequency predict children’s mathematical gains and does the frequency of teachers’ mathematics language in content strand group differentially predict children’s mathematical gains (number and operations group versus other math group)? These questions are an important next step from the past research that only looked at the impact of number and some operations language on child mathematics outcomes. “Early mathematics” includes a broader range of content language.
The TMLM was selected because it collects information on the frequency of teachers’ mathematics language across both content strands and instructional settings. The definitions of the constructs were built from previous research; however the geometry and measurement constructs were expounded upon due to the limited earlier work in this area (Klibanoff et al., 2006; McCray, 2008). For number and operations, the constructs were quite similar to earlier work by Klibanoff et al. (2006). They were made more specific and the exact words were clarified. In comparison to these two strands, the geometry and measurement constructs were far more broadly defined (fitting in a wide range of related utterances and concepts). For example the measurement category included: standard measurements, requests to measure, and comparisons. These categories were purposefully broad, as it was the first time research on this type of language was part of the discussion of teacher math talk in the preschool classroom. It is also noted that not all words fit perfectly into one category. Choices had to be made. For example, the word “more” was defined as a comparison and put in the category of measurement. However, it could be argued that “more” might be put in the number or operations categories. The Child Mathematics Assessment (CMA) was selected as the child outcome measure because it is a comprehensive assessment that covers various content strands and was well supported by research as an effective measure of preschool children’s math outcomes (Klein & Starkey, 2001; Klein, Starkey, & Wakeley, 1999).

The results showed that on average teachers used 216.52 mathematics utterances in two hours. However there was large variation across teachers. A majority of the language was related to number at 54.78%. Measurement language represented 31.42%, geometry 10.36% and only 3.44% of the language was related to operations. This makes
sense in conjunction with the research that shows teachers mainly use number talk (National Research Council, 2009). The combined construct of all mathematics language (number, operations, measurement and geometry) was not significantly predictive of children’s gains in mathematics ($r=0.044$, $p=0.134$). However, the combined construct of number and operations language was significantly predictive of child outcomes in mathematics ($r= 0.013$, $p<0.022$). Teachers’ who used more number and operations language had students who scored higher on the child mathematics assessment across the year.

The fact that the “combined number and operations” construct was significantly predictive of child math outcomes is important for two major reasons. One, it supports Klibanoff et al.’s (2006) findings. Two, it expands on Klibanoff et al.’s work because the measures used expanded number and operations language. For example, this study included words like “again, another, several, many, and a lot.” These words are more general quantity and operation references, as opposed to “1.” The operations category was also expanded to include more specific mathematics terms like, “divide, minus and calculate.”

The next question is, why was “other math language” not predictive of child outcomes in mathematics? There could be a variety of reasons why the measurement and geometry construct was not significantly predictive of outcomes. Measurement language was the broadest category, and it was comprised of two main categories: standard measurement and comparisons. The standard measurement category included utterances referring to “units” and “requests to measure attributes.” The comparison category had two parts as well, “attributes that qualify” and “sequence (time and space).” The most
common measurement utterances referred to sequences of time and space, including words such as: later, during, while, after, and next. It is possible that the comparison words symbolize a more complex level of “measurement” while the CMA represented a simplistic test of measurement (comparisons between length and quantity, not time and space). The next step for research might be to take the measurement language and break it up into more specific, smaller categories of language. Since it represents 31.42% of teachers’ language in our sample, it would be valuable to examine relationships between just standard measurements or just comparisons and see how these two separate categories relate to child math outcomes.

The reasoning behind why the geometry category might not have been significantly connected to child outcomes in mathematics is different. The category of geometry was not broad. It was narrowly defined. The geometry category had two sub-categories: shape references (i.e., circle, oval, square) and shape attributes and descriptions (i.e., curve, angle, flat). Very rarely did teachers use words referring to the latter. Most of the language that fell into the geometry category was a shape reference. Additionally, teachers often just repeated the same shape word over and over as a method of instruction. There were rarely moments where children were asked to embark on understanding or analyzing a shape, as opposed to simple repetition or labeling. This type of low-level cognitively demanding language (merely repeating words over and over again) might have limited the possible connection with children’s outcomes. Theoretically, if children are just taught to repeat and not to “understand” it would limit their applied knowledge.
Below is an excerpt from a teacher who explained a small group shape activity to the class in large group and then the children embarked on creating art out of shapes:

Teacher: I am going to show you what I did with the shapes. Ok. I used many shapes and I did my own piece of art. Ok? Yes. Ok? You are going to become artists too. You are not going to paint. You are just going to use the shapes to create your own design. You can pick any color of shapes and you can glue them anyway you want. Think about it beforehand you pick the shape Michael. Which ones you really like and what you want to do? So think carefully what you want to do. I am going to let you pick the big triangle. Ok. And when you go to the table you can decide what shape you want to glue to the big triangle. So I used small triangles, big circles, small circles, big square, I used a small circle, inside a square. I used ovals, rectangle and a square, ok? You will be able to do the same thing. Let me bring the triangles so you can pick the color that you want. (15, 2)

The teacher used a lot of shape “words” but there was very little engagement regarding the students understanding of shapes or shape comparisons. In fact, the students did not give any responses when she asked questions. In a way she wasn’t expecting a response since she did not leave time for the answer. After this instruction the children used shapes to make their artwork and then they were asked what they made. When children finished their work the teacher said, “What is that?” and each child responded with their own idea: for example, “superman.” There were no questions during the small group that asked children to identify shapes or apply knowledge about geometry concepts.

Another teacher chose to integrate shapes into large group time by reading a shape book, into small groups by having a shape art activity, and she even used shapes in the transition from large group to free play. This teacher did ask the children to apply some shape knowledge but again, this higher-level language that engaged the children in exploring concepts was minimal. During small group, when the rest of the class was in
free play, the teacher played a game called “shape detectives” where the children had to place certain shapes on objects that looked similar. Here is an excerpt from that small group:

Teacher: Can you find a square? Go stick it on a square. Do you want to find some shapes too? What shape is this? [child is inaudible] You’re very close. It goes around and around it’s called a circle. A circle. Go find a circle and stick it on there. Stick it on there. Are you ready for another shape? Put the magnet away you can come get another shape. Sarah would you like to be a shape-ok, then put them back in the blocks. Come get another shape? Fabulous. Are you ready for your next shape? Ok. Ok, you ready? Next one is..ok. Yep. You found one. We’re just sticking them up though. Did I give you one? Next is, somewhere in the classroom anywhere find a…you did, you found a square. Nice job. You found a triangle. Here’s your next one. Did you find one of these yet? Go find a triangle. You found one. Oh, thank you. What shape is that? Go find this one. Did you do this one already? Ok, what shape is that? What shape is it? You found it. You did find a circle (8, 3).

This teacher did ask children to apply shape concepts and make comparisons. She did not use her language to question the children about why they made certain choices. Instead, she explained that a circle “goes around and around.” In this example the teacher is prompting slightly higher-level thinking from the children by involving them in finding shapes. The children used mainly gestures in response. However, if she involved them in a more in-depth discussion about the process, she would be able to assess their understanding and promote even deeper conceptual understanding.

This research on content language shows that more needs to be known about teachers’ mathematics language relating to measurement and geometry. Interestingly, the “other language” category represents roughly 42% of the language that was gathered. There is a large amount of other mathematics language occurring in the preschool classroom. The findings affirm what early research has shown, that teachers’
mathematics language relating to number and operations does have an important connection with child math outcomes in the preschool years (see Figure 11).

![Figure 11. Relationship between Teachers’ Mathematics Language and Children’s Mathematics Outcomes](image)

Moving forward, only the combined construct of number and operations was used in the analysis. Next, we look at math language in various contexts.

**Teachers’ Math Language: Instructional Settings**

The analysis of teachers’ language use across various instructional settings is an exploratory look at what is actually occurring in the classroom and an attempt to examine and expand current research. Where is teachers’ mathematics language occurring, and do instructional settings mediate the relationship between teachers’ mathematics language and child outcomes as the current workshops suggest? Montie, Claxton and Lockhart’s (2007) work illustrated that the amount of time spent in each setting can predict children’s outcomes. They found that spending more time in free play in the preschool classroom led to higher long term outcomes in both reading and mathematics. McCray (2008) found that teachers’ mathematics language that was used in non-circle time (non-
large group) activities was connected to higher child outcomes in mathematics. The next subset of questions aims to answer: What is the frequency and rate of teacher math talk across three instructional settings (circle time, small group, and free play) and how does the frequency and rate of language use in settings differentially predict children’s mathematical gains?

The current work on instructional settings is suggestive yet problematic. Instructional settings provide a context for the learning process. The use of instructional settings is varied across teachers. This analysis provides us with a different way to look at what might be impacting teachers’ language and how teachers’ use instructional settings to provide instruction in the content area of mathematics. When discussing the results, it needs to be made clear that the relationship between settings, teachers’ language, and child mathematics outcomes is not a clear, consistent connection. Though valuable in many ways, this work is merely a first step in trying to explain the relationship and draw connections across classrooms.

The following questions should be kept in mind as they place the results of this under researched area in a larger, theoretical context: What do these “settings” represent? Do teachers behave differently in each setting? Is there anything consistent in terms of teachers’ mathematics language across settings? What do these findings indicate about instruction and interactions between students?

**Descriptive Statistics on Teachers’ Mathematics Language in Three Instructional Settings**

The descriptive statistics show that teachers used more number and operations language in large group (53.64%) than they did in the two other settings combined. The
time spent in large group, as well as the rate of number and operations language was also greater. The average time spent in large group was 28.89 minutes, small group was 22.11 and free play was 16.85. The rate of language in large group was 2.09 utterances/minute in large group, 1.76 in small group and 0.78 in free play. These findings indicate that teachers are talking about math content more in the large group setting, and small group is a close second in terms of rate of language. However, free play does not seem to be used as a setting where math content is discussed much at all.

Interestingly, the time spent in free play was minimal for the two-hour observation. Most preschool programs spend a great deal of time in this setting, so this finding was surprising. I believe it could have to do with how free play is being defined in this study, how teachers are using the free play instructional time, and the timing of the actual observations. This result suggests that free play is not used for the intentional teaching of mathematics, and that teachers are not picking up on the opportunities to integrate math content into moments that are primarily driven by children’s interests. In addition, the amount of time spent in free play may have been limited because the observations occurred first thing in the morning. Perhaps more free play happened later in the day. As this is a significant issue, follow-up analysis is presented in an effort to explain this phenomenon.

Teachers’ Mathematics Language in Each Setting and its Relationship to Child Math Outcomes

The question, “how does the frequency and rate of math language use in settings differentially predict children’s mathematics gains?” was examined by running two linear regression equations in HLM. The findings showed three complex and interesting results.
First, one of the most significant findings of the entire study was that the frequency of teachers’ combined number and operations language in small group was highly significantly predictive of child math gains ($r=0.023, p<0.01$). A second interesting finding was that the frequency of teachers’ number and operations language in free play was negatively predictive of child math outcomes ($r=-0.056, p<0.049$). Finally, the rate of number and operations language in each setting was not predictive of child math outcomes. The final estimation of variance components related to this analysis showed that more variance needs to be explained outside of these rate constructs ($p<0.023$). This could include the differences regarding frequency of teachers’ math words or the differences regarding time. Rate combines these two unique constructs.

It is important to discuss the element of time spent in each setting and how this might have impacted the results. Rate might not have had an impact on child outcomes because of this factor. Time spent in each setting may be powerful because of its comparative valuable with the amount of number and operation math words. On average teachers’ used 2.09 words/minute in large group, 1.76 words/minute in small group, and 0.78 words/minute in free play. Rate is a comparative category that includes frequency of words and time. If time plays a large role it could skew the results.

An HLM analysis was run to examine the relationship between the time spent in each setting and child math outcomes. The analysis showed that the amount of time spent in large group ($p<0.927$) and small group ($p<0.615$) was not significantly predictive of child math gains. Surprisingly, time spent in free play was negatively predictive of children’s math gains ($r=0.08, p<0.024$). This means that the more time spent in free play, the increased likelihood that children would have smaller math gains. This section
will detail the results listed above, including this confusing finding regarding free play. It will also give possible explanations for the results within the context of earlier research.

**Small group.** One of the most interesting and exciting findings is that the more mathematics language related to number and operations that teachers’ used in small group, the higher the gains the children had in mathematics. This was not true for the frequency of number and operations language in large group or free play. So what does this finding say about teachers’ math language use and the setting of small group? In small group, it is about the amount of math input the children receive overall, not the intensity (rate) of language. Another explanation could be that the small group might be one of the best settings to teach higher-level concepts, or go more in-depth in a discussion. The teacher may be able to provide more feedback, there might be a greater sharing of ideas between students, and/or teachers might be able to assess knowledge and give more tailored instruction due to the setting.

One specific finding supports this idea that small groups might enable teachers to work with students on more complex mathematical ideas. Rudd et al. (2008) argue that some strands demand a higher level of thinking from students, operations being one of them. The rate of teachers’ operations language in small group was significantly predictive of child outcomes and that the coefficient was 2.76 (p=0.003) in this study. This means that teachers who used more operations language per minute in small group had students with a 2.76 increase on the Child Mathematics Assessment (CMA) across the year. This result is being reported because of its low p-value, indicating a high chance of it being a significant finding. It should be noted that judging operations as a stand-alone construct is not ideal since there were very few operation strands recorded.
However, if operations language is indeed more cognitively demanding for students, perhaps using small group to teach these higher-level concepts is ideal.

These findings are valuable because they expand on the research in three ways. They advance the understanding of mathematics teaching in the small group setting. Similar to work that has been done regarding literacy instruction in the small group setting (Connor, Morrison & Slominski, 2006; Morrow & Smith, 1990; Phillips & Twardosz, 2003), mathematics teaching in this setting is also connected to child outcomes. It partially supports the work of Montie, Claxton, and Lockhart (2007), who found that when children spent more time in free play and small group settings in the preschool classroom they will have higher gains in mathematics and literacy. This work adds an important piece that is both content specific and identifies a specific element of instruction: teachers’ mathematics language. The small group setting does mediate the relationship between teachers’ math language and children’s outcomes in math. Finally, it provides empirical evidence for the argument made by the National Research Council (2009): although small groups are rarely used to teach mathematics in the early childhood settings they should be used more often.

**Free play.** One of the most complex findings was that the frequency of teachers’ mathematics language in free play was negatively predictive of child outcomes in math \((r=-0.056, \ p<0.049)\). This means that the more number and operations language teachers’ use in free play, the lower child gains in mathematics. This seems contradictory to the literature. Free play is highly valued in the field of early education. The use of play is a believed to be key in promoting children’s learning during the preschool years.
Further analysis offers some possible explanations for this negative relationship. When free play is coded using the TLML, it is defined as “a setting when the teacher was not directing an activity but following the students’ lead.” To be coded in the free play category, the majority of the students had to be involved in free play or center activities, and the teacher could not be doing an instructional 1-on-1 or a small group activity that was separate from free play. The amount of time spent in free play was surprisingly low, especially because the two-hour period that was coded happened as close to the start of the day as possible. These two factors are critical.

What does this finding say about the setting of free play and how teachers are using it? How could it be so contradictory to the literature about the value and importance of free play? Qualitative analysis was used to reflect on these questions. Two major trends were observed regarding teachers’ behaviors and language during free play: most teachers did not engage with children during free play (perhaps due to the fact that the sample was taken at the start of the day when they had other tasks to attend to), and the teachers that did engage with children did not typically integrate mathematics concepts into their work with children. It is also important to note that when teachers did use math language during free play it was often used as a management tool. For example, teachers often said phrases similar to, “You have five more minutes.” Overall, teachers don’t seem to be using free play as a means to provide mathematics instruction to students. There is a great missed opportunity here, since free play is arguably the most child-centered instructional setting that is used in the preschool classroom.

When we look at the language occurring during free play teachers were rarely engaging in discussions with the children. The language seems to represent transitions,
management and an emphasis on social-emotional development. When children are split
into centers there is typically some discussion of how many children can go in each area:

How many people go on block number two, on the second block? Is his
ticket hanging? Ben, come here please. Ben come here please. Jasmine,
how many people go on the second block. You got it. Can you put the two
back since they dropped? Ben, I’m waiting for you buddy. Come here. I’m
going to explain it to you again. The center is already full. There are
already four people there. (7, 3)

Another example is from a teacher who spent a lot of time during free play getting
children settled in centers, then she went around and helped children figure out disputes,
and finally, she picked up by sorting objects. There is mathematics in the sorting task,
however, she did not use her language to scaffold the child’s sorting process. Here are
two excerpts of her language during free play:

What happened? What happened? Come with me. Come with me. Lets
go get some water. What happened? Need some water. No? You want
something to drink? No? Did you hurt your finger? Did somebody hurt
your feelings? Did somebody take your toys, hmmm? Did somebody take
your toys? Which toys did they take? Your toys? Show me the toys?
(12, 3)

Thank you Daniel. What a good worker you are. You are putting all the
shapes in here? [She sorts shapes next to child]. That one goes over there.
Good job of sorting Daniel. (12, 3)

Many teachers started free play with the students and then worked with a small
group. This shortened the amount of time they were engaging with children during the
setting of free play and inherently caused most of their language in free play to be about
management. For example one teacher tried to run a small group but was constantly
distracted by children engaged in free play. In the middle of the group she turned to the
block area and said, “1.2.3. Good? Kate is everything ok in there? Ok. I thought I heard
somebody get upset.” Then a child approached her about not wanting food and she
responded, “Avery if you really don’t want to you don’t have to but I just want to remind you of how sad you were last time when you didn’t have something to eat. So do you want to eat? Yes or no? [He shakes head] Ok. Go wash your hands” (111, 2). This is all management related language.

Another trend that appeared through the recordings was that when teachers that did seem to engage with children and prompt higher level thinking concepts during free play they did not emphasize mathematics concepts. These teachers would go from center to center engaging in dramatic play, asking questions at the sensory table, and prompting discussions about letters at the writing center. However, though their language facilitated discussions and prompted higher-level thinking in the children, teachers rarely even touched on mathematical concepts. Most of their language was about problem solving during social conflicts, developing higher-level pretend play skills, and mastering literacy related concepts. These are all very important components of the preschool classroom, but it is interesting that some of the most engaged teachers did not integrate any mathematics into their work with children in this setting.

These interactions seem contradictory to the research that discusses valuable teacher language during free play (Burman, 2007; Howes, 1990; Kontos, 1999). More teacher training needs to be provided that helps teachers’ interact with students during this setting. This training should focus on how content, such as mathematics, can be integrated into the setting of free play, and how teacher language can help facilitate the exploration of math concepts in increasingly complex ways. Free play is a powerful setting where children have the opportunity to explore and investigate concepts on their own. The teacher can play such an integral role in expanding these ideas through the use...
of materials and through the use of language. It is about how teachers’ view their role in each setting, and how they use the tools they have to enhance interactions.

**Large group.** The highest frequency of math language occurred in the setting of large group and children spent the most time in this setting. However, frequency and rate of teachers’ math language was not connected to child outcomes. Every teacher that was observed led a large group during the two hours. Most of them involved taking attendance, calendar, reading a story, and leading an activity or discussion of some kind. The mathematics language usually occurred during the attendance and the calendar. A few teachers read stories related to mathematics concepts. If so many teachers are using mathematics language during large group time, why is the frequency and rate of this language not connected to child outcomes in mathematics? To provide possible answers to this question, we will look at an example from large group:

Teacher: And what number was yesterday? [kids call out] So we’re going to see what’s tomor—today. One.

Children (chanting together): 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

Teacher (joins in as some kids start to mix up numbers): 19, 20, 21, 22, 23, 24, 25, 20…5! Yeah. Nathan…put it up there. What number did he put up there?

Children: 25

Teacher: 25, very good. Now let me ask you a question that has something completely different to do-- it doesn’t have anything to do with the calendar. How many fingers do you have?

Children: 10

Teacher: And how many toes do you have?

Children: 10
Teacher: So if we added your fingers and your toes together, how many would we have?

Children: (mumble)

One Child: 10

Teacher: 1, 2…. [Children start to count but it’s mumbled]

Teacher: 11, 12, 13, 14, 15, 16, 17, 18, 19, 20. So if you add 10 fingers plus 10 toes is how many?

One child: 20. (111, 3)

In this example, the teacher leads the discussion. She asks the questions and counts with the children when they get confused. All of her questions are offered to the entire group, not to individual children. The whole class also does the counting. There are two times when one child answers the questions and interestingly, these are the two questions that involve slightly higher level thinking skills (for example, adding numbers together). This example is fairly typical of the large groups that were observed.

As shown in the example, only one child answered the harder questions. It is unclear if the other children knew the answer. This example supports the literature that generalizes that the whole group setting typically has a lot of teacher directed language as compared to the other learning formats (Maloney, 2000). Though this is certainly not true in every classroom, the study showed that most of the large groups included mathematics language that provoked low-level cognitive responses from children (such as rote counting being led by the teacher). Also, since most of the children’s responses were collective as opposed to individual, it is not clear if all the children were participating and
understanding the math concepts. This could influence the impact of teachers’ mathematics language on children’s learning during large group time.

However, the results aren’t simply a result of the context of “large group” but rather the way in which teachers use the setting of large group. This has to do with teachers’ knowledge of practice and their knowledge of content. If a teacher believes that numeral recognition is an important element of mathematics in preschool they will teach it. If a teacher believes that understanding the concept of quantity is more important, they will prioritize this concept. Attitude and experience also plays a role. If a teacher doesn’t really understand certain mathematical concepts she is less likely to teach that idea. She is also less likely to develop a more engaging method of teaching that concept. The key to improving large group instruction is to improve teacher education in the area of mathematics so teachers are confident and competent in this content area.

**Summary: Instructional Settings**

The work on teachers’ mathematics language use in the three main instructional settings and its relationship to child math outcomes prompts some interesting questions for future research. There does seem to be some connection between the setting that mathematics language occurs in and child outcomes, especially with reference to small group. Figure 12 shows this representation.
Figure 12. Mediating Effects of the Small Group Setting on the Relationship between Teachers’ Mathematics Language and Child Outcomes in Mathematics

However, analyzing “instructional settings” across teachers can be difficult since so much depends on how the individual teacher chooses to use each setting and the interaction that the teacher has with the child. This work doesn’t seek to determine whether or not it is the actual setting of “small group” that causes the teacher to have this interaction, or the teacher that allows the setting to foster this interaction. This work shows that context and interactions between teachers’ and children through language are both valuable pieces to the story. As Vygotsky argues, language is about the interaction. The next step is to look at what is really happening between the teacher and the child. How does teachers’ mathematics language impact the learning process of the child?

**Teachers’ Math Language: Level of Cognitive Demand**

Current research supports the argument that teachers’ use of language that engages children in high-level conceptual thinking is important to cognitive development
Though this type of language has been noted as being important to developing mathematical understanding in young children (Cross, Woods, & Schweingruber, 2009) no study has looked directly at the type of cognitively demanding mathematics language that is being used by teachers in the preschool classroom and how this language connects to child outcomes in mathematics. This study attempts to broaden the concept of “teacher math talk” by asking: What is the level of cognitive demand in teacher mathematics talk in the preschool classroom and how does this relate to child outcomes in early mathematics performance?

The Measure of Cognitive Demand in Math Language (MCDML) was created by the author as a method of assessing the level of engagement and cognitive thinking that the teachers’ language provokes in the child. It was designed to provide further insight into how language can represent the interaction between the child and the teacher. Due to the small sample size of 15, it was unlikely that significance would be found in the analysis connecting the type of language to child outcomes in mathematics. However, this measure did provide insight into the type of cognitive demand in preschool teachers’ mathematics language that is occurring. It also raised some interesting questions for future research.

**Four Content Strands**

A smaller sample of 15 teachers was used for this analysis. For every teacher, language was recorded for two hours. The MCDML revealed that the majority of math language was of low-level cognitive demand, 72.53%. This language is defined as math vocabulary and utterances that don’t offer any questioning or prompting towards the
child, basically, it doesn’t engage the child in a back and forth exchange but merely exposes them to math words. Examples include, “Here is a circle” and “You have three toys.” Comparatively, 26.19% of the language was medium level and 1.28% of the language was high level. These findings are very important. Overwhelmingly, teachers’ math language in preschool classrooms is more about exposure and less about engagement and promoting children’s deeper understanding of concepts.

The initial analysis of cognitive demand in teachers’ math language focused on language across all four content strands (number, operations, measurement and geometry). Combined number and operations language made up 64.93% of total language. The most practiced category was low-level number and operations language (44.39%) and the second category was low-level measurement and geometry language (28.14%). The smallest category of language was high-level number and operations language (0.75%) and the second smallest was high-level measurement and geometry language (0.53%). It makes sense that the most popular type of language used was low-level, regardless of content strand. Teachers are using a remarkably large amount of low-level language.

**Combined Number and Operations Language**

Based on the earlier findings that connect frequency of number and operations language to child outcomes in math, the frequency of cognitively demanding language related to number and operations is of significant interest. When just this language was examined, there were only 17 utterances of high-level language out of 1470 total number and operations utterances. This represents 1.15%, while medium level language was 30.48% and low-level language was 68.37%. With a majority of the language being low-
level, it is clear that when teachers are exposing children to math words they are not simultaneously challenging them to think deeply about concepts as often as they could be.

**Relationship to Child Math Outcomes**

As expected, the analyses did not reveal significant connections between the level of cognitive demand in teachers’ math language and child outcomes in math. This was not surprising due to the small sample size. However, the weighted analysis that compared low-level number and operations language with medium/high level number and operations language (giving low-level language one point, medium language two points, and high-level language three points) showed that low-level language had a negative coefficient ($r = -0.017$, $p < 0.412$) and medium/high level language had a positive coefficient ($r = 0.016$, $p < 0.327$). Though not significant (indicating that there is a chance of error in the result), this suggests that low-level language could be a negative predictor of child math outcomes while medium and high level language could be a positive predictor of child math outcomes. The same directionality appeared when low-level language versus medium/high level language across all four content strands was analyzed as a predictor of child outcomes.

In order to fully examine the differences that the various levels of teacher language can promote in children’s cognitive understanding, we must look more closely at the interaction between the teacher and the child. Two sets of examples are given. The first is a sample of low-level cognitive demanding language.
Example 1. *Taking Attendance in Large Group*

Teacher: Juan is 7 and Jerry is 8. Let’s count to see. 1,2,3,4,5,6,7,8 (some children count with her). How many children? Boys? Are in school?

Child: 10

Teacher: 8. Ok let’s find… shah. Let’s find the numbers. Ok. Jose come find number 8. Which is number 8? This one, this one or this one? (He points) That’s good. And find number 9 Raheem? This one or this one? This one or this one? This one or this one? It’s up here. Very good. (18, 3)

Example 2. *One-on-one*

Teacher: You know, I really need you to try hard and not make guesses ok? Try again. How ‘bout this one. What’s this? This one? What’s that? Good. This one? This one? Alright. Thanks Hannah. Good bye Hannah. You can go back to your area. Karen. Sit down. What number is that? K, good job. Devon, it’s time for you to get off the computer. Karen, you can go on the computer. No, Karen’s going. Yes. Eva, I need you for a minute. I need you for one minute. What number is this? Good job. (106, 4)

*Child’s responses were inaudible.*

Example 3. *Calendar in Large Group*

Teacher: Boys and girls look up here. 3 and a 1 and 2 is? Who knows what a 1 and a 2 is?

Children: 12.

Teacher: A 1 and a 2 is 12. 2009 this is the date. Today is the…. Thurs? What’s today?

Child: (Screams out) Thursday

Teacher: What’s Today?

Child: Thursday

Teacher: What’s today? Thursday. Look up here and read. (12, 4)
These three examples are considered samples of low-level cognitively demanding language because the teachers’ language only prompts children to have basic recall of facts. In the first example the teacher ignores the children’s incorrect responses and states the correct answer, without trying to decipher where the confusion in the thought process might be. In the first and second example the teachers ask children to identify numerals. This requires the child to engage in basic numeral recognition without challenging them with more in-depth mathematical concepts. This is still meaningful but it is a low-level skill.

Interestingly, example 3 is rather confusing as the phrasing by the teacher, “A 1 and a 2 is?” could be $1+2=3$ or indicate the number 12. In this example the children are asked for numeral recognition again. All three of these examples involve teachers who are looking for one correct answer from the child. They do not want the child to engage in higher-level thinking such as problem solving. This type of low-level language made up 72% of the entire mathematics language the 15 teachers used.

The second set of examples is from one teacher. The examples show the teacher’s use of medium and high-level cognitively demanding mathematics language. This language clearly engages the children in more conceptual, advanced thinking by asking them to explain their thought processes.

Example 4. *Large Group Book Reading*

Teacher: Who wants to start reading the moon book? Sit down if you do. If you do not want me to read the moon book stand up. If you’re standing you do not want me to read the moon book.

Child: Yes!

Teacher: So why do you say that Alex?
Child: Because there’s more people standing.

Teacher: There’s more people what? There’s more people sitting than standing? How many people are standing?

Child: One, two, three, four, five, six.

Teacher: How many people are sitting?

Child: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Children: Yay!!!

Teacher: Why are you guys cheering? Tell me how you know that we’re going to read the book?

Child: Cause there’s more people.

Teacher: And thirteen, you just know cause thirteen is bigger than six?

Child: That’s’ bigger.

Teacher: That’s a bigger number. It is a huge number. You’re right. Ok. Alright. We’ll just read. [Continues to read book and the conversation turns to the table of contents]…

Teacher: Do they all have ten chapters?

Children: Yes

Teacher: They all have 10 chapters. That one had ten chapters. It is.

Child: That one had more.

Teacher: Some of the chapters are different amounts of pages. Ok. The prologue is first. It’s just like what?

Child: 10 on carpet.

Teacher: It’s just 10, like the 10 rocks just like we have on the carpet. Very good observation Kayla. There’s 10 rocks in the middle of our carpet and there is the number 10. Thank you Kayla for pointing that out. Ok, the prologue… (6, 2)
Example 5. *Discussion of Attendance in Large Group*

Teacher: Adam, do you think we need to count or can we look down here?

Children: 19, 19, 19

Teacher: Why do you say there’s 19? How do you know, ok there’s two at home, so how do you know there’s nineteen?

Children: Sarah is gone and…

Teacher: Sarah is on vacation and Ethan is not here so what does that make?

Class: 19

Teacher: 19 and how do we know this?

Child: Because if you want to take 2 away.

Teacher: 21 and we take 2 away that’s 19. What do you think? Does everyone agree?

Child: If we have Ethan and Sarah that would make 20 but if they aren’t here that means we have 19.

Teacher: Thank you. Good. I like your guys thinking here. Thank you so much kiddo. Great. You are absolutely correct, we have, and when you look at this we have, how many kids are in this classroom?

Children: 21

Child: 21 and then when we take 2 away that gives us 19.

Teacher: You should really kiss your brain on that one. Can you find the number 19 in there for me? (Child finds 18). That’s a 1 and an 8. What does a 19 look like?


Teacher: Did it get bigger or smaller as the week went on?

Children: Bigger, smaller.
Teacher: Who says bigger? If you say bigger, stand up. Ok, let’s look, on Monday, Ari, can you move away so we can see the whole number? Monday, there was twenty-one kids here. Tuesday there was how many kids?

Children: 20.

Teacher: 20. On Wednesday there was 20. On Thursday there was 19. So is the number getting bigger? Or smaller?

Children: Smaller

Teacher: Smaller. Because…

Child: Because its going backwards.

[skip]

Teacher: On Monday we had all 21 kids here. And today we only have nineteen. Did you notice that we had more room on the carpet?

Children: Yeah. (6, 3)

This teacher asks several open-ended questions that promote high-level cognitive responses from the children. This high-level questioning allows the children and the teacher to engage in ongoing back and forth exchanges about mathematical concepts. The children add as much to the conversation as the teacher. She also uses their answers to build off their understanding and knowledge. By asking questions such as “Tell me how you know?” and “Why do you say there’s 19?” the teacher leads the students to think further about how they got the answer and not to just recall facts. The students are able to explain their reasoning and express their ideas.

In examples 4 and 5 there are several ways in which the children to apply their mathematical knowledge in meaningful ways. To name a few, one child compares the number ten to the number of rocks on the carpet (example 4). There are many comparisons about quantity and size. For example, in the discussion of attendance in
large group (example 5) the teacher asks “Did it (the number of children in attendance) get bigger or smaller as the week went on?” This question asks the children to recall knowledge and make comparisons about these quantities.

Teachers’ medium and high-level language only made up approximately 27.5% of the total observed language. By looking closely at the examples, it seems evident that the children exposed to the medium and higher-level language are able to express their ideas, reasoning, and explanations about the mathematical concepts. Though the level of cognitive demand was not connected statistically to children’s outcomes in mathematics, probably due to the size of the sample, the examples illustrate clear differences in children’s responses based on the type of language the teacher uses. The richness of the discussion, the engagement of the children around mathematical ideas, and the in-depth knowledge the teacher provoked with the higher-level cognitively demanding language, is clear. This dynamic must be considered when teachers’ language is researched and discussed in professional development. Language is about the exchange of ideas. It is about enabling the children’s process in the moment of learning.

**Limitations and Implications**

**Limitations**

There are two main areas of limitations with this study: sample (size and selection) and measurement (selection and interactions). Choices were made in each of these areas that are important to note when reflecting on the results of this work. The most significant limitation was the amount of teachers that were used in the sample that analyzed cognitively demanding language. Due to the stringent standards required by this sample only 15 teachers were selected. Teachers had to have four full recordings that
were matched to live coding of the TMLM. The recordings had to have clear language samples. Each teacher had to also have a full sample of 8-10 children that were assessed using the CMA at two time points (fall and spring). This sample size limited the likelihood of finding a result that had a p-value < 0.5. With a larger sample size it would have been more likely that a significant effect would have been detected and that this potential effect wouldn’t have occurred just by chance. A larger sample size would have also offered more opportunities for qualitative analysis.

Two other limitations regarding the sample selection must be noted: diversity of teachers and diversity of students. The demographics of the sample included teachers that were a mix of state Pre-K teachers from CPS and Head Start teachers. This is beneficial in that it created a more diverse sample of teachers to gain information from but the fact teachers came from different programs might have affected the findings in some way. No differences between the two groups were examined and since they came from different programs, there might be within program differences such as similarities regarding context of school environment or class size. For example, Head Start programs integrate some shared components into their schedule, such as breakfast and self-care time. These might have cut into the time that could have been used for large group, small group, or free play. There also could be differences in teacher education. Though all the teachers were certified, Head Start programs could have teachers with less formal education than CPS teachers. This could be based on opportunities and requirements.

The child sample also had limitations caused by lack of diversity within the sample. Though the children were randomly selected from the consents that were received, parents did have to sign the permission form. This could have skewed the
sample by including children that had parents who were more involved or may support research. In addition, children who had IEPs were dropped from the sample, eliminating some diversity. This means that the sample does not give a clear picture of all types of children that are part of a typical preschool program.

Like any measure, the TMLM, CMA, and MCDML also had their limitations. The TMLM and the MCDML are both newly developed measures. A plausible issue with new measures could be that they aren’t verified with a broader sample. Like any measure that is coded live, even when reliability is reached, there is some subjectivity that exists with the coding process. This is true of the TMLM and the MCDML. During one-time coding, it is possible that some language was missed. One time coding means that one person is listening to the language as it takes place in the classroom or on the recording. Though the sole purpose is to focus primarily on the teacher’s language for two hours; that is a long time to sustain attention on one task. Coding might be particularly difficult if a lot of mathematics language occurred quickly. For example, if a teacher says a number several times in a row it is possible that some math language might have been missed. This study recorded one type of language, “math words” in several different ways. This connects and extends on past research however, it does leave out many other elements of “language” that must be explored in future work if we are to get a complete sense of what is happening in the classroom.

The final limitation is about the interaction between the TMLM and the CMA measures that were used to compare teachers’ mathematics language and child math gains across the year. The CMA as a measure of mathematics gains covers all the math content strands to varying degrees. It assesses number, operation, geometry,
measurement, algebra, and data analysis. This might impact the findings, since the independent variable (TMLM) only looked at number and operations language at one point and the dependent variable (the CMA) assessed more general mathematics knowledge in the child. It is important to note that since each strand in the CMA was only represented by 1-3 questions, the sub-scales are too small to connect to child outcomes. This study provides evidence that teachers’ number and operations language predicts general mathematical gains, not just number and operation specific knowledge. It was not possible to use just the number and operations findings from the CMA. This child assessment sample would have been too small. It is interesting that number and operations language used by teachers connects to more general math knowledge in the child. However, this might explain the lack of significant findings that existed regarding geometry and measurement. Perhaps this type of teacher mathematics language did not connect to more general math knowledge. The questions follow: would this type of math language have predicted child math outcomes that were content specific (i.e. assessing only geometry or only measurement concepts)? Are number and operation words the best proxy for a lot of important teaching factors?

Finally, it is important to note that this study aimed to look directly at teachers’ mathematics language regardless of curriculum or instructional approach employed by the teachers. This is not a specific limitation, but rather a choice, since it was the goal of the study to examine the differences at the teacher level regarding mathematics language output. This was particularly challenging when instructional settings were examined because teachers’ use of settings can be so dependent on their purpose, approach, and philosophy regarding interactions with children. The case study examples were used as a
way to investigate the interactions between the teacher and the child in a more in-depth way.

In future studies, it is important to consider curriculum and instructional approach when looking at the teacher-child interaction or the language that is occurring in this interaction. Curriculum choice provides insight into the attitudes and knowledge the teacher has about practice. For example, if the teacher employs a Montessori approach to early childhood education, the children should have a lot of independence and choice. This is a central tenet of Montessori education. This may mean the purpose of free play or small group is to really let the child take the lead. It is likely that this could be reflected in the interactions and language the teachers’ use with the children. Curriculum also sets the goals for the children in the program. If one program aims to teach children only a few number concepts (such as number names and numeral recognition), while another program has goals of teaching children more in-depth number concepts (cardinality, ordinal numbers, etc.), there are likely to be differences in teacher math language and instruction. Again, this is not a limitation, but an important element to consider when examining the findings of this work and thinking about future research.

**Implications**

This study presents significant findings in the area of teachers’ mathematics language. It broadens the conceptualization of teachers’ mathematics language, it explores the influence of instructional settings on teachers’ use of mathematics language, and most importantly, it investigates how teachers’ mathematics language might be able to facilitate higher-level conceptual development for young children in the area of mathematics. The studies prior to this work emphasized frequency of math utterances by
teachers, mainly just covering number words (Klibanoff et al., 2006; McCray, 2008). Though research on literacy instruction talked about the complex interactions between the teacher and the child, nothing detailed this process regarding mathematics. In addition, the vast amount of work about instructional settings gave no clear message of how teachers used these settings to instruct young children in content. This work not only expands the way teachers’ math language has been researched, but it provides us with clear next steps for future research.

The current study expanded the research scope of teachers’ math language by focusing on a broader range of mathematics content. Though number language was still the most prominent form of teacher math language, this work found that there was also a large amount of geometry and measurement language occurring in the classroom. Focusing on a broader range of math language is important because all five content strands are essential components to early mathematics development. In addition, it shows that teachers are not just focusing on number and operations language, as has been previously argued (National Research Council, 2009).

This study confirmed that number and operations language is still the best language predictor of children’s outcomes in mathematics. This is a significant finding because it confirms earlier work (Klibanoff et al., 2006; McCray, 2008). It also supports the argument that this type of language is the narrowest and clearly defined. This is valuable because it confirms that the frequency of teachers’ number and operation words is an important predictor of child math outcomes.

Beyond altering the definition of teachers’ math language to include a broader range of content, this study contributes to the field by greatly expanding the
conceptualization of teachers’ mathematics language. The measure that was created to examine the level of cognitive demand in teachers’ mathematics talk and the findings that show how much teachers’ language use can produce engagement in children around mathematical ideas, is extremely valuable. Now there is a broader and more in-depth understanding of what mathematics language can be and what this language can do.

Professional development and teacher education programs need to place a greater emphasis on early mathematics education. Based on the findings from this work professional development needs to draw teachers’ attention to the range of mathematics language that is valuable to children’s mathematical development. “Math talk” is more than frequency of number and operation words, though this is certainly important. Teachers should be educated in the range of content strands and how these concepts can be developed through interactions involving language. Teachers need a greater understanding of math concepts (number, operations, measurement, geometry, algebra, and data analysis). They need to know how to recognize and engage children in talk, for example through stories, to simplify these concepts so young children can understand them. Content learning in the early years of school is becoming more and more important. We now know the vast differences that exist in teachers’ math language and also how this language can impact children’s outcomes in both the short and long-term.

The drive and ability of teachers to facilitate interactions where children are highly engaged in figuring out, and applying mathematical concepts is key. Professional development needs to place a greater emphasis on educating teachers about how to have in-depth conversations. Teachers need to be shown how to understand the child’s perspective and knowledge through observation and listening. They need to be taught
how to validate the child’s understanding and expand on their ideas. Teachers need to know how to use their language to facilitate deeper cognitive understanding within the child around a conceptual idea. Learning is about the discourse and the process, the all-encompassing interaction. This study shows that teachers are not using very much medium or high-level cognitively demanding mathematics language in preschool classrooms. In order to make this happen teachers need more training in math knowledge, math teaching practices, and in the important role that language can play in the learning process. This is a very important change that must occur if we are to advance children’s understanding of mathematical ideas and create lasting positive effects of early mathematics education.

The most important finding from the exploration of teachers’ mathematics language in the three major instructional settings was the significant impact that this language in small group has on children’s outcomes in mathematics. This finding validates the work that has been done on literacy instruction in small groups (Connor, Morrison & Slominski, 2006; Morrow & Smith, 1990; Phillips & Twardosz, 2003). Professional development should emphasize the use of small group for mathematics instruction. Specific education regarding the value of small group and how it can be used to provide instruction that meets the specific needs to students should be provided to teachers.

Another important finding was how little the setting of free play was being used by teachers to discuss content. Very few teachers even engaged with children in discussions during free play. Teachers are missing out on a very important opportunity to build off of children’s interests by integrating discussions and content into this setting.
Professional development needs to train early childhood teachers how to purposefully interact with children during the three different major settings. It can educate teachers on the value of free play, and explore the many ways teachers can facilitate in-depth learning for children during this setting. It can target the teacher’s role and language use during free play. Particular discussion about how to integrate mathematics instruction into free play would be extremely valuable.

Similarly, professional development on mathematics instruction during large group will want to include ideas that go beyond calendar and attendance. It will want to explore how teachers can have extended conversations with children about more complex mathematical ideas. It should integrate literature, inquiry based investigations, and a range of discussion questions to help teachers get children thinking about bigger mathematical concepts. This type of teaching will enable children to move beyond just giving the correct answer to really understanding what the correct answer means and how they got there.

This study moved the current research on teachers’ mathematics language in the preschool classroom forward in several ways. This is represented in Figure 13.
The circles that represent the teacher and the child overlap because their interaction is essential to the learning process. The qualitative research showed us the significance of these interactions. This is also in-line with the theoretical work representing the teacher-child relationship (see Figure 1).

The solid line signifies the relationship between teachers’ mathematics language (frequency of number and operation words) and child outcomes. The other dashed line represents medium and high-level cognitively demanding teachers’ mathematics language. It is dashed because it represents a possible connection. It also has arrows...
pointing to both the teacher and the child to represent the reciprocal interaction that is possible with this type of language.

The circle that is the farthest away represents instructional settings. The only solid line represents small group. It points to the line representing teachers’ mathematics language because the study showed it did have a mediating effect on this relationship. The other two arrows represent the settings of free play and large group. They are dashed and outside of the circles because their impact is unknown.

Future research can continue to advance the conceptualization of teachers’ mathematics language in the preschool classroom. In terms of the findings regarding content strands, further work needs to be done on the relationship between measurement and geometry language and child outcomes in mathematics. What subsets of this language relates to child outcomes (i.e., measurement comparisons)? Is this language predictive of child outcomes in math when the child assessment tool is strand specific? This language is under-researched and we know now that it represents close to 45% of the total math language occurring in the preschool classroom. Additionally, it is important to note that not all mathematics conceptual development involves verbal language. It is necessary to explore other types of math learning such as gestures and symbols. How much of this is happening in early childhood classrooms?

The MCDML measure could be used to assess a larger sample size. Since there is so little medium and high-level cognitively demanding language being used in the classroom, a larger sample size might show connections to child outcomes in mathematics that this study did not find. A longitudinal study on the impact of teachers’
mathematics language during the preschool years is suggested since this might bring out additional effects.

This work leads us to ask new questions about how the interaction between the teacher and the child can lead to deeper conceptual understanding of content in the preschool classrooms. Math teaching is about the interaction, the value in the conversation, the learning that is promoted via discourse and the exchange of the ideas. Teaching is complex and constantly evolving. Future research can use this new conceptualization to examine language patterns more closely. Researchers could look at how teachers’ mathematics language leads to children’s responses, how teachers answer children’s questions about math concepts, and how teachers’ own attitudes and beliefs about mathematics influence their instruction. Future research can also look at how selected curricula influences teachers’ instruction in mathematics. Teachers’ mathematics language is important because of the connection it facilitates between the teacher and the child around mathematical concepts and ideas in the early childhood classroom. It is a vital tool in the learning process.
APPENDIX A

CODING CATEGORIES FOR TEACHER MATHEMATICS LANGUAGE MEASURE
NUMBER

NUMBERS, statements of AMOUNT/OCCURRENCE, and REQUESTS to report/identify them
- *One, two, three…*
- (counting is one tally, use of single number name is one tally)
- First, second, third…
- Single, pair, double, trio, triple, quartet, quintet…dozen
- Another, again, several, many, a few, a lot, frequently, seldom, often, rarely, ever, never, sometimes
- What number is this?
- How many…? How much…? How often…?

OPERATIONS:
- add
- subtract
- multiply
- divide
- share
- separate
- combine
- calculate
- plus
- minus
- sum (as a verb)

*NOTE: Counting aloud (for example, “1, 2, 3…”) should be given just one tally. Saying “This one…that one… which one”—phrases that specify a particular thing as opposed to indicating how many thing(s) – do NOT qualify.

MEASUREMENT

Standard Measurement
- UNITs:
  - inch
  - foot
  - pound
  - gram
  - quart
  - cup
  - teaspoon
  - mile
  - miles per hour
  - degrees
  - minute
  - hour
  - day
  - week
  - month
  - year
  - morning
  - noon
  - afternoon
  - evening
  - nighttime
  - midnight

- REQUESTS to MEASURE any of the attributes above
  - how much?
  - how long?
  - how fast?
  - how tall?

Comparisons
- Attributes THAT QUALIFY
  - length
  - height
  - general size
  - width
  - girth
  - depth
  - weight
  - age
  - temperature
  - speed
  - sufficiency
  - sequence (SEE BELOW)
  - general quantity (more than, less than, the same as, equal, most, least)

- SEQUENCE (TIME AND SPACE)
  - later
  - earlier
  - simultaneously
  - during
  - while
  - still
  - at the same time
  - yesterday
  - today
  - tomorrow
  - prior
  - subsequent
  - before
  - after
  - next
  - start*
  - end*
  - beginning*
  - ending*
  - last/this/next
  - week/month/year
  - this morning/afternoon etc.,
*NOTE: start, end, beginning, and ending only qualify when they refer to a clear sequence of either events or spatially arrayed things.

**GEOMETRY**

**SHAPE references**

<table>
<thead>
<tr>
<th>Circle</th>
<th>Square</th>
<th>Triangle</th>
<th>Rectangle</th>
<th>Rhombus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond</td>
<td>Trapezoid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallelogram</td>
<td>Oval</td>
<td>Pentagon</td>
<td>Hexagon</td>
<td>Octagon</td>
</tr>
<tr>
<td>Dodecahedron</td>
<td>Spiral</td>
<td>Quadrangle</td>
<td>Cube</td>
<td>Sphere</td>
</tr>
<tr>
<td>Pyramid</td>
<td>Cylinder</td>
<td>Pillar</td>
<td>Column</td>
<td>Bridge</td>
</tr>
<tr>
<td>Spire</td>
<td>Tower</td>
<td>Hill</td>
<td>Mound</td>
<td>Valley</td>
</tr>
<tr>
<td>Arch</td>
<td>Island</td>
<td>Peninsula</td>
<td>Bay</td>
<td>Line</td>
</tr>
<tr>
<td>Island</td>
<td>Pillar</td>
<td>Column</td>
<td>Bridge</td>
<td>Platform</td>
</tr>
</tbody>
</table>

**Shape attributes and descriptions:**

<table>
<thead>
<tr>
<th>Area</th>
<th>Diameter</th>
<th>Circumference</th>
<th>Radius</th>
<th>Angle</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve</td>
<td>Slope</td>
<td>Round</td>
<td>Pointy</td>
<td>Oblong</td>
<td>Squared-off</td>
</tr>
<tr>
<td>Squat</td>
<td>Flat</td>
<td>Convex</td>
<td>Concave</td>
<td>Symmetrical</td>
<td>Arched</td>
</tr>
<tr>
<td>Hollow</td>
<td>Angled</td>
<td>Radiating</td>
<td>Curved</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES


VITA

Emma Whitman was born and raised in Ann Arbor, Michigan. Before attending Erikson Institute and Loyola University Chicago, she attended Wellesley College, where she earned a Bachelor of Arts in Psychology and History, in 2005. From 2005-2007, she attended Bank Street Graduate School of Education, where she received a Masters in Science of Education in General Childhood Education.

Whitman received the Irving B. Harris Fellowship at Erikson Institute. While at Erikson, she worked as a Graduate Research Fellow on the Early Mathematics Collaborative and served as a Teaching Assistant. She also served as the Director of Early Childhood at St. George’s Episcopal School in New Orleans, Louisiana. Currently, Whitman is the Director of Rye Presbyterian Nursery School in Rye, New York. She lives in Mamaroneck, New York.