LISTENING TO MATH TALK: A QUALITATIVE STUDY OF PRESCHOOL CHILDREN'S MATH LANGUAGE DURING PLAY

A DISSERTATION

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BY

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Cheryl Y. Mixon entitled, "Listening to Math Talk: A Qualitative Study of Preschool Children's Math Language During Play." I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Child Development.

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Dean of the Graduate School

DEDICATION

To my Lord and Savior, Jesus Christ, thank you for making all things possible.

To my wonderful parents, Pearl Mixon and the late Ray Mixon, Sr. whose love and support have motivated me to excel in all my endeavors. Your prayers and encouragement have always sustained me through the most challenging times.

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ABSTRACT

CHERYL Y. MIXON

LISTENING TO MATH TALK: A QUALITATIVE STUDY OF PRESCHOOL CHILDREN'S MATH LANGUAGE DURING PLAY

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The purpose of this phenomenological study was to explore preschool children's use of math talk in their play. The research questions investigated how children used math talk and how the children communicated changes in their mathematical thinking. Piaget's theory of cognitive development and Vygotsky's social cognition theory were employed to establish the theoretical lens that framed this study.

The ten participants in the study were enrolled at a non-profit child development center in North Texas. The children ranged in age from two years and nine months to three years and eleven months. As a participant observer, the researcher engaged in play with the children over an eight week period during the free center play time. The observations were recorded to capture the talk and the non-verbal interactions during the play. Provocations were applied to stimulate math talk through questions and comments in response to the children's talk and play. Field notes and photographs were also collected during the study.

The data was analyzed through two cycles of coding and discourse analysis. The findings revealed six themes regarding the children's use of math talk: 1) reinforcement of classroom rules, 2) directing and protecting the play, 3) managing and accessing materials, 4) making comparisons, 5) descriptions and requests, and 6) declarations. Two themes were revealed regarding the communicated changes of the children's mathematical thinking: 1) sharing and applying knowledge and 2) restating ideas. The findings indicated children have multiple uses for math talk and the application of mathematical knowledge is evident their daily experiences.   Implications for early education professionals and parents were discussed as well as future research recommendations.

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CHAPTER I

INTRODUCTION

Young children explore mathematical concepts in their daily experiences and interacting with the environment provides opportunities for them to engage in problem solving, quantification, estimations and many other mathematical tasks. As they begin to dialogue with adults and peers, their communicative abilities become more sophisticated, allowing adults to understand their internal mathematical thinking. This blend of mathematical thinking and communicative language results in “math talk” and listening to the math talk of a child permits the listener to understand the mathematical processes of the child (Houssart & Mason, 2009).

Logico-mathematical knowledge refers to the construction of relationships between and among objects (Kamii, 1982) and grows out of young children’s internal processes as they interact with the natural dilemmas that occur in their world. This construction of relationships is internal and imperative for mathematical thinking to develop. Hence, the mathematical thinking in young children cannot be directly imparted; instead, it must be constructed. Through math talk, young children share their construction of mathematical knowledge with both peers and adults (Anthony & Walshaw, 2009).

Math talk is essential for young children to test their mathematical thinking. Social interactions can create a setting in which preschool children can develop logico-mathematical knowledge (Kamii & DeClark, 1985), which prompt children to organize their mathematical thinking and concepts to express their ideas clearly (Copley, 2000). The organization of the concepts is then communicated to others and this social exchange of ideas is foundational for mathematical knowledge and understanding to progress. It is the math talk that must be explored to ensure adults cultivate an environment that extends young children's construction of logico-mathematical knowledge (Lesh & Doerr, 2000).

Statement of the Problem

The relationship between math and language was inferred over 50 years ago in a commentary presented by I.H. Brune that highlighted the language evident in mathematics teaching and the importance of language in comprehending mathematics (Brune, 1953). Brune further explained math language was representative of the constructs occurring in one's thinking. Though this examination was specific to more advanced mathematics, the relationship is apparent in early mathematics as well. Early education leaders have taken note of the importance and included language as a necessary component for learning mathematics (Fuson, Clements, & Beckmann, 2010).

The joint position statement of the National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) suggests young children's mathematical understandings are constructed through experiences that involve depth and that the learning environment should encourage children to "develop, construct, test and reflect" on their mathematical thinking (NAEYC & NCTM, 2009, p.1). The math talk that occurs as children dialogue with others in solving problems allows them an opportunity to organize their thinking and receive feedback that may or may not agree with their ideas (Houssart, 2009).

The National Council of Teachers of Mathematics (NCTM), in a publication on mathematics education, proposed children should be capable of clearly communicating their mathematical thinking. Further, the organization suggested communication should be a key component in math curriculum (Fuson, Clements & Beckmann, 2010). Though their position and suggestions indicate the importance of communication in mathematics, educators often feel compelled to impart every aspect of math, often disregarding children's input and ideas (Ginsberg & Ertle, 2008). This approach preempts young children's exploration and construction of mathematical thinking and hinders math talk.

As young children engage in math talk, comments and questions from their peers and others can cause them to question their current thinking (Copley, 2000). Copley suggested this preponderance of doubt can provoke mental conflict which motivates children to explore additional ideas to resolve the dissonance. Piaget proposed that when children are faced with such a mental conflict, or disequilibrium, they are prompted to make the necessary accommodations to their initial thinking (Piaget, 1950). Kamii, Miyakawa, and Kato (2004) explained that mental relationships within the individual shifts and adjusts when presented with an alternative way of understanding. Therefore, social exchanges of the young child can result in a reorganization of the mental construction from within. In a review of the math talk that occurred independent of the teacher, Houssart (2009) found the children's math talk brought about new interpretations and knowledge of the mathematical ideas discussed. The children made discoveries and shared their findings with each other, sometimes resulting in disagreements and, at times, adjustments to their initial thinking. Understanding this natural process of the child can guide educators in appropriate interactions that reveal both the child's thinking and rationale behind errors rather than simply correcting them (Kamii, 1982). As educators understand the necessity of math talk and its impact on learning they will more likely apply strategies that expand children's mathematical thinking.

In the Reggio Emilia Approach, educators employ a strategy that reveals an understanding of a child's internal process through provocations which can stimulate and expand children's mathematical thinking (Linder, Powers-Costello, & Stegelin, 2011). Provocation has been defined as listening to the child's talk and creating an authentic situation that provokes additional thought and action (Fraser & Gestwicki, 2002). In doing so, children's math talk can reveal the accommodations and changes in their mathematical thinking. Siegler and Lin (2010) suggested when children as young as five years old are encouraged to talk through and explain correct and or incorrect solutions to a problem, their mathematical thinking increases and more advanced approaches are applied to future problems.

Though the exploration of math talk has begun, much remains to be investigated. Despite the extant amount of research regarding young children's ability to conduct mathematical manipulations, research has not extensively reviewed young children's communication regarding mathematics. Language has been confined to the periphery of mathematics research in early childhood (Bishop, Clements, Keitel, Kilpatrick, & Laborde, 1996). Several research studies have acknowledged young children's advanced grasp of various mathematical concepts but have neglected the math talk that occurs as young children experience mathematics in their daily lives. The exploration of math talk is necessary to guide educators in creating environments and situations that can extend young children's mathematical thinking.

Significance of the Study

Early mathematical experiences of young children are inevitable and necessary for mathematical thinking to be constructed. For the educator to understand the mathematical thinking, listening to math talk is imperative to gain insight far more valuable than any nonverbal task (Evens & Houssart, 2009). In this study, math talk was explored and described to further inform the field of early childhood education regarding mathematical thinking of the preschool child.

When dialogue occurs it allows the speaker to describe and clarify his or her experiences, which may prompt the speaker to realize his or her thinking as never before considered (Pollio, Henley, & Thompson, 1997). Using a phenomenological approach, this study explored young children's math talk during free play, a setting that encouraged them to converse with their peers. The researcher stimulated mathematical thinking and talk through mathematical questions and comments. The children's mathematical thinking and strategizing, made apparent through their math talk, provided the researcher with an understanding of how they communicate mathematical processes.

Expanding the understanding of preschool children's mathematical thinking and use of math talk influences both mathematics and early childhood research. Bridging the gaps between these fields of research strengthens the knowledge base that informs the instructional approaches in mathematics utilized in the early childhood classroom. The early childhood professional benefits from this study by understanding how to take research and influence their instructional practices and develop strategies to provoke mathematical knowledge construction in young children.

Theoretical Framework

This phenomenological research study was informed by two early education theories, Jean Piaget's theory of cognitive development (Piaget, 1950) and Lev Vygotsky's social cognition theory (Vygotsky, 1962). Each of these theories offered insight into how young children develop cognition and communicative abilities, both necessary components of math talk. The influence of these theories guided the framework within which the study was conducted.

Piaget proposed that young children's cognitive development is based on their construction of knowledge (Inhelder & Piaget, 1964) and that the construction occurs internally, though it can be impacted by external happenings. Three types of knowledge, as he explained, are all necessary for children's knowledge construction: physical, logico-mathematical, and social (Piaget, 1970). The physical knowledge entails observing objects and discovering properties of the objects; it is an experimental activity permitted free of adult guidance or interruption (Thomas, 2005). Logico-mathematical knowledge involves manipulation of objects wherein the information is gained as the child explores relationships between the object and his or her acting on the object. Piaget explained this concept further with the example of a set of pebbles. As a child manipulates a group of pebbles he or she eventually realizes the number of pebbles remains the same regardless of formation, be it vertically, horizontally or circular (Piaget, 1970). Social knowledge refers to the child being guided through the object interaction by a more knowledgeable person, who provides the knowledge (Kamii, Miyakawa, & Kato, 2004). Each of these types of knowledge, though some occur outside of the individual, impacts the internal construction of knowledge (Kamii, 1982).

Piaget suggested that educators should observe children in their physical and logico-mathematical experiences as they approximate, reason and reflect on their thinking (Piaget, 1970). According to Ojose (2008), it is this experience that constitutes the discovery and construction of knowledge that deepens and clarifies a child's thinking. Both Piaget and Vygotsky viewed the learning process as internal and personally relevant, though influenced by external experiences and social interactions.

Lev Vygotsky's social cognition theory was complementary to this study as well. His theory indicated the communication a child has with others promotes deeper levels of the child's understanding (Vygotsky, 1962). Children's mathematical thinking, though personally constructed, can be influenced by "dialogic interactions," which entails the back and forth exchange of language.

Vygotsky’s research highlighted the link between language and thought (Vygotsky, 1962) wherein the use of language and the ability to manipulate it internally provides children a realm from which they can express their thinking. The relationship between language and thought is not a thing but it is a process, which Vygotsky (1962) described as a convergence of the two, referred to as verbal thought (Thomas, 2005). In moving from thought to word, thoughts undergo many changes prior to being communicated verbally and this verbal thought indicates children’s ability to express their mental activity. They are capable of organizing thoughts and memories to solve problems. To study the internal process of mathematical thinking it is necessary to externalize the process through children’s language, an external activity (Vygotsky, 1962). This study’s intent was to externalize mathematical thinking by connecting it to language.

Shayer and Adhami (2010) applied a theoretical foundation steeped in both Piaget and Vygostky in their study of mathematical learning of five to seven year old children. The children were given mathematical problems to discuss with a partner on how the problems should be solved. Through their dialogue, the children’s mathematical thinking improved, suggesting math talk positively influenced the learning process.

The Reggio Emilia Approach was influenced by Piaget’s and Vygotsky’s theories (Dodd-Nufrio, 2011). The approach is that of a socio-constructivist model which views the child as a constructor of his or her knowledge through social engagement with both adults and peers. The natural learning environment created in the Reggio Emilia

Approach, with the use of provocations, incites children to investigate, explore and test possible solutions to problems faced (Linder, Powers-Costello, & Stegelin, 2011). This study applied structural aspects of the Reggio Emilia Approach, specifically through the use of provocations from the researcher that may stimulate mathematical thinking in free play.

Research Questions

Engaging in some form of play is the most naturalistic approach to observing, interacting and conversing with young children. The researcher engaged preschool children during play with comments and questions intended to generate math talk. To understand the use of math talk, the following research questions were investigated.

1. How do preschool children use math talk?
2. How do preschool children communicate changes in their mathematical thinking?

Definitions

This research of preschool children's math talk was investigated and the following terms were applied throughout this study.

Construction of knowledge refers to the process of children having experiences that inform their thinking (Inhelder & Piaget, 1964). The information is added to their memory and thoughts.

Logico-mathematical knowledge is the coordination of relationships constructed by the child (Kamii, 1982). The relationships are derived from the internal workings of the child's mind.

Math talk is the specific language that occurs in mathematical discussions, comments and questions (Klibanoff, Levine, Huttenlocher, Vasilyeva, and Hedges, 2006). It is intended to communicate the mathematical thinking within the child.

Mathematical thinking is described as the cognitive process that involves mathematical concepts such as numeracy, capacity or classification (Burton, 1984).

Phenomenological research refers to the possible meanings of the lived experience of the individuals or a probable explanation of the experience (van Manen, 1990).

Provocations are defined as listening to and observing the child and developing ideas to provoke additional thought and actions of the child (Fraser & Gestwicki, 2002).

Subitize refers to the ability to state the number in a small set of objects without counting (Kaufman, Lord, Reese & Volkman, 1949).

Delimitations

This research was conducted in a child care facility in the North Texas area. The focus was on one preschool classroom for three-year-olds who had not yet received or been exposed to formal math instruction. Delimiting the study to this group of preschoolers prevented the math talk from being contaminated by formal math language unnatural to young children. Though teacher interactions were a natural part of the classroom setting, this fell outside of the focus of the study of the preschoolers' math talk. The children were presented with math provocations shared during child-directed free play in the classroom. The observations and interactions occurred within the classroom to create a natural setting of play evident in the daily schedule of the children.

Summary

Mathematical learning occurs internally and is constructed through young children's experiences in their daily environments. The internal construction, influenced by both physical and logico-mathematical experiences, can be made external when verbalized through math talk. This expression of mathematical thinking through math talk can allow children to clarify their thinking to both the listener and themselves. In addition to the math talk generated by daily experiences, provocations made in the typical daily experiences create an opportunity for preschool children to expand and elaborate their mathematical thinking and expressions.

Though the communicative component of mathematics has been heralded as important by NAEYC and NCTM, the research on math talk has remained limited. Mathematics research and early childhood research have not fully examined the combination of math and language. It is this dearth of research that this study addressed.

Theories from Piaget and Vygostky served as the foundations to the theoretical framing of this study. Piaget's assertion of the knowledge construction young children engage in based on their physical and logico-mathematical experiences was a focus of this research. Further, Vygotsky's contention of the relationship between thought and language and its impact on advances in thinking also served as a primary source of information throughout this study.

The current study explored the use of math talk as children interacted and played with materials made available during their free play time. The researcher sought to answer the research questions through listening to the children's math talk. With a phenomenological lens, the dialogue among the children was closely examined to understand their experiences and knowledge regarding mathematics. As such, this study informs the early childhood professional on appropriate interactions surrounding mathematical thinking in young children.

CHAPTER II

REVIEW OF LITERATURE

Introduction

From birth, children are immersed in mathematical experiences in their daily lives and their knowledge evolves from the most basic concepts, such as recognizing a change in quantity to more advanced concepts like enumeration and problem solving. Though mathematical thinking cannot completely be understood in young pre-verbal children, the development of language allows another facet in understanding the internal mathematical processes. This study expanded the understanding of mathematical thinking in preschool children through their use of language.

Mathematics research in early childhood merits further exploration of young children's mathematical processes. In a review of early mathematics research, Anthony and Walshaw (2009) highlighted the lack of studies that focused on the preschool years. In their examination of mathematics journals, they found that mathematics research in early childhood was not represented in these publications, and the few studies available were generally confined to early childhood journals. For example, in reviewing the *Journal for Research in Mathematics Education*, over a ten year span only three research articles were published that focused on preschool children, despite its specialization in mathematics. This review of literature focuses on related studies of young children's mathematical thinking and the communication of mathematical thinking in the early childhood and elementary years. The research questions examined were:

1. How do preschool children use math talk?
2. How do preschool children communicate changes in their mathematical thinking?

Piagetian Theory

The development of cognition is an internal process occurring within the child and yet includes both internal and external events. Jean Piaget's theory of cognitive development proposed the process of knowledge acquisition in young children. Piaget described three types of knowledge acquired in the early years: physical, social and logico-mathematical (Piaget, 1970). Both physical and social knowledge are acquired through external experiences of the child. The physical knowledge can be defined as knowledge of properties of objects a child observes. Social knowledge develops as a child interacts or socializes with a person, prompting new ideas and thoughts of the child. The third type of knowledge, logico-mathematical, is an internal process where the child constructs the knowledge. This internal construction, as proposed by Piaget, was a guiding principle for this study.

As a child manipulates and experiments with the objects in the environment, his or her logico-mathematical knowledge evolves. The logico-mathematical knowledge is based on the child's perception of the relationships between and among objects (Kamii, Miyakawa, & Kato, 2004). The relationship has not previously existed within the child's reality. Construction of logico-mathematical knowledge is dependent on the child's interpretation of how objects are related, a knowledge that cannot be taught (Kamii, 1982).

Logico-mathematical knowledge requires a much deeper sense of assimilation or organization of information into existing schema (Piaget, 1970; Thomas 2005). The level of assimilation apparent in logico-mathematical knowledge is a restructuring or reinvention of data. The child is not merely adding observed data to the existing schema, but is constructing new data that is added. The original data is transformed by the new relationship derived from the experimental coordination of action performed by the child. The transformations of the initial knowledge result in a higher operational structure (Piaget, 1970). For example, a teacher shares a basic addition fact with a child. For the fact to become reality, the child must experience the combination of two sets into one larger set. The child must reinvent the addition fact personally to develop logico-mathematical knowledge. If this process does not occur, the fact is merely rote memorization and the child is unable to apply it to any other situation.

The application of knowledge to varying problems lies in the intellectual autonomy of the child. Piaget suggested the goal of the teacher should be to develop "intellectual explorers" (Piaget, 1970, p.51) who can transform the adult thought into personal reality. Education, according to Piaget, cannot succeed without children experiencing authentic activity that provokes construction of knowledge. He further suggested the receptive methods of education, wherein a child receives what is told without individual experimentation, should be replaced with active methods. The active techniques involve children’s actions and coordination of objects, a research process unique to the child that is reflected upon to reinvent the information at a personal level. Mathematical thinking necessitates active methods of experiments and actions wherein a relationship is realized personally and internally.

Mathematical Thinking

Mathematical thinking in young children has been explored in children as young as three months of age. Researchers such as Wynn (1992), Lipton and Spelke (2004) and Izard, Dehaene-Lambertz and Dehaene (2008) have contributed to research evincing the mathematical abilities of infants and toddlers. Examining mathematical abilities in children this young has its limits, as these children are essentially non-verbal. Some researchers viewed the approaches applied as ideal in understanding the thinking processes regardless of children’s language abilities (Baroody, Lai, Li, & Baroody, 2009). Other studies, for various reasons, have focused on young children completing mathematical tasks to inform the process of mathematical thinking. Regardless of the approach, children’s mathematical thinking is exemplified through their play and intuition.

Math Play

Mathematical learning in the preschool years occurs through children’s play as well as planned experiential activities. It is a balance between the two that is imperative for children to develop their mathematical thinking (Anthony & Walshaw, 2009).

Through children's play, mathematical ideas are developed and challenged (Ginsburg, Lee & Boyd, 2008).

Clements (2001) described the need for preschool children to experience mathematics in their play. In a discussion of mathematics in the preschool classroom, Clements opined that mathematics is a natural component of young children's play. The playful interactions promote development of an informal logico-mathematical knowledge as described by Piaget, which is more complex than often realized. In play, preschoolers are motivated to explore mathematics but need an adult to observe and recognize opportunities to provoke and clarify their mathematical ideas through accessible materials or dialogue. Young children exhibit their mathematical thinking through talking, dramatization, and art, all of which are represented in their play.

Edo, Planas and Badillo (2009) created and analyzed a mathematical context of play, prompting shared and cooperative experiences among five and six year olds. Proponents of Piaget's idea of knowledge construction, the researchers examined whether simulated mathematical play contexts increased children's mathematical thinking. It was proposed that children need a combination of autonomy in play and effective teacher interventions to move mathematical thinking forward. The teacher intervention would require elements of reality that children could incorporate into their symbolic play. The social interactions among the children would move their thinking from subjective knowledge to objective knowledge, promoting the construction of shared and public mathematical thinking. To answer the research question, 26 children in Spain were exposed to a bakery shop, which they eventually created in the symbolic play. The teacher gradually added mathematical concepts of buying and selling, calculator use, addition and money. The children were encouraged to illustrate their activities in response to the teacher's questions, such as explain your buying, to represent their use of mathematical concepts. The information surrounding the play scenario was gathered through observations, audio and video tapes, interviews and written work of the children. Upon analysis of the data, five categories of mathematical application were revealed: quantitative use of non-numerical words (i.e. all, some, more), use of numbers without quantitative relevance, mathematical use of numbers and calculator use. During the final interview with the children, 22 of them gave a clear explanation of the mathematical concepts related to their bakery shop play. The study concluded that as children articulate their thinking in a play context surrounding math concepts, the mathematical thinking becomes progressively more sophisticated.

Van Oers (2010) examined children's mathematical thinking at work in the context of play. The study explored the most appropriate approaches to enhancing young children's mathematical thinking, whether in a play context or a more formal approach. Within a Vygotskian framework, van Oers explained how young children develop mathematical thinking through activities that are authentic in their cultural practices. Further, all learning must have a personal meaning to the individual which occurs in participation and reflection on the actions he or she has performed. Based on a compilation of research conducted with 275 five to eleven year- old children at Free

University Amsterdam, van Oers argued that instructional strategies in mathematics should be based on the play of children. The more knowledgeable adult assigns mathematical meanings to the children's actions in play, utilizing a context that is relevant to the children. In one of the observational studies two five year-old children were building a castle and needed a long block to complete the structure. One child took two smaller blocks and put them together. The teacher noticed and expressed that the two small blocks were the same length as one long block, assigning the mathematical meaning to the child's solution. Van Oers concluded within the context of play children are able to expand their mathematical thinking, constructing new ideas and concepts.

Björklund (2010) sought to uncover toddlers' strategies that promote learning mathematics in a qualitative study of children from two Finland child care centers. Björklund proposed toddlers' learning of mathematics depended largely on relationships and environments. In practical situations and communicating with others, toddlers' mathematical thinking was developed. Twenty-three children, ages 13 to 45 months, were videotaped in their interactions in the classroom, which resulted in 45 hours of observational data. The analysis, which was limited to 65 episodes, suggested children's mathematical thinking was evident in their social interactions and communication, both verbal and non-verbal. Björklund suggested the interactions allowed children to experience different meanings from their peers and become aware of their own thinking. When toddlers listened to their peers, they were able to clarify their mathematical thinking in unique ways. One example of this process occurred when a group of children were eating cereal and discussed quantity, with the terms little, much and much more, using their fingers to show their meaning. This was a practical situation the toddlers experienced that required some level of mathematical discussion and understanding the perspectives of each other. Björklund suggested the discussion among the toddlers led to new understandings.

Lee (2012) argued that mathematical concepts were evident throughout the play of New Zealand toddlers on the playground. Videotaped observations of one to three year old children over the course of four months resulted in 45 hours of toddlers at play. After a critical analysis of the play, Lee identified seven mathematical concepts evident in the play. Space, number, measurement, shape, pattern, classification and problem solving were all described through the children's play. Lee's rich description of the children's play included children's filling a jug with sand, patting the top to fill it up and dumping the sand, exhibiting knowledge of capacity. The exploration of the toddlers, without interference from an adult, served as the basis for mathematical thinking in its earliest stage. Lee suggested teachers encourage this free exploration and take note of the play that interests children and build on it. Through opportunities for exploration, children will construct and expand their logico-mathematical knowledge as they act on the materials and environments surrounding them (Piaget, 1970).

Kaartinen and Kumpulainen (2012) proposed that children's identity is negotiated and re-negotiated while constructing new ideas during the discussions that occur in play. The researchers suggested that the feedback children give and receive allows a revision to their initial thinking, enhancing their mathematical learning. The study focused on the types of feedback that influence mathematical knowledge as well as the challenges that arise from joint construction of math knowledge. The study included 11 three-year old Finnish children, the teacher and a researcher, and analyzed a small group interacting with the teacher in play during two videotaped sessions. Egg cartons, counting bears, paper clips and geometrical shapes were provided for the children's play. In the first session the children were applying one-to-one correspondence between pictures of colored shapes and objects with the teacher's assistance. The interaction highlighted the discourse moves or exchanges, which involved counting, extending questions and suggestions. In the second session, the teacher invited other children to join in the play, prompting negotiations of the materials available and how to use them. As children added bears to the egg carton, the teacher posed questions of how many more would fit in the egg carton. The children did not immediately agree on the answers but, with the teacher's assistance, the children eventually decided on the correct answer. The researchers concluded socially shared experiences promote mathematical knowledge construction.

Math Intuition

Intuition refers to the natural ability to notice mathematical relationships based on real experiences (Jung, Kloosterman, & McMullen, 2007). The mathematical thinking of young children is steeped in their intuitive thinking, which may be a result of their experiences. Intuition is the starting point for mathematical thinking and, though not initially accurate, prompts the acquisition of mathematical knowledge. For example, the young child who sees a tall glass and short glass intuitively knows the tall glass will hold more. Though the intuitive thought may be inaccurate, when faced with a different thought, it stimulates disequilibrium, which is necessary for new learning to occur (Piaget, 1950). Math intuition has been highlighted in studies revolving around problem solving and measurement strategies applied by young children.

Problem solving. Jung, Kloosterman, and McMullen (2007) reviewed studies where math intuition was exhibited during problem solving tasks of three to eight year old children, revealing problem solving abilities in young children. Through a socio-constructivist approach titled Cognitively Guided Instruction, first grade children were presented with word problems and then asked to find a solution and explain to others their process. The teachers refrained from sharing formal mathematical strategies and encouraged children to apply their own strategies. Findings suggested that the children had significant gains substantiated by the conceptual understanding evident through their processes and discussions. Children approached the problem differently but came to the same conclusion. As children experience real world problems they reference their computational intuition to find a solution. Another example shared in the review identified the process of a five-year old child presented with a problem of sharing 12 bananas with a friend. The child attempted to solve the problem with her fingers, an intuitive strategy that had previously worked well but was ineffective with the number of bananas. She then wrote out the numbers in a rectangle in two rows then drew a line down the middle of the shape. As the teacher observed, he suggested she use counters to solve the problem. Her intuition served as foundational in solving the problem but was challenged, resulting in learning a new strategy. Jung, Kloosterman and McMullen concluded that when teachers value and listen to young children's mathematical intuitions they promote a setting that provokes more advanced mathematical thinking.

McCrink and Spelke (2010) examined young children's intuitive understanding of multiplication prior to formal instruction. Sixteen five to seven year old children in the Boston area, divided into a younger and older group, were given tasks in three experiments requiring them to determine which set had more after some objects were multiplied by two, two and a half, and four. An experimenter and a child were seated together in a testing room where the child was shown an object which was then occluded behind a box. Once the set was hidden, a wand appeared indicating multiplication of the object. A comparison set was then shown and the child had to choose whether the set was larger or smaller than the hidden set. The children successfully chose the correct set 82% of the time for the multiplication by two, 75% for multiplication by two and a half, and 69% for multiplication by four. The researchers reviewed the possibilities of strategies children may have applied in the experiments, concluding none of the strategies would be successful across all three experiments. Further, the findings suggested children have an innate multiplicative ability that is engaged prior to any formal multiplication instruction. McCrink and Spelke deduced a combination of intuition and instruction would enhance conceptual understandings of challenging math concepts.

Charlesworth and Leali (2012) suggested problem solving in mathematics reveals the processes of young children's intuition and mathematical thinking. Children's acquisition of mathematics concepts, per the researchers, occurs through naturalistic, informal or adult guided experiences. In a review of mathematical problem solving, Charlesworth and Leali described guidelines for assessments outlined by NCTM, assessment methods and suggestions for evaluating young children's problem solving strategies. The assessment methods reviewed, observation, informal conversations, and interviews, each had strengths that could provide educators with a clear understanding of children's mathematical thoughts. In considering observational assessments, the researchers proposed young children's informal mathematics experiences with real world problems allow adults to assess their mathematical thinking. Based on teacher observations of children, ages18 months to 6 years, citing an example from each age group, the children found and solved problems independently in their naturalistic settings. In addition to observations, informal discussions with children balanced with questioning from the teacher, can yield information regarding a child's methodology in problem solving. Interviews with the verbal children provided additional insight and prompted reflective thinking of the children as they explained their process. Charlesworth and Leali concluded observing, conversing and interviewing young children can provide invaluable information into their mathematical thinking.

Measurement. Kamii and Russell (2010) investigated children's understanding of the measurement of time and children's progression from intuitive time to operational time with the replication of an experiment Piaget conducted. Young children's intuitive time is generally based on observable features. One-hundred and eighty-four children in one school, from kindergarten to fifth grade, were shown pictures of an apple and a pear tree planted a year apart. Initially, the older apple tree appeared larger than the pear tree but in the final picture the pear tree was larger, despite being a year younger. Ninety-four percent of the kindergarten and first grade children focused on the size of the tree as opposed to the age and were unable to correctly identify the older tree, highlighting the intuitive thought that bigger is synonymous with older. The second through fifth grade children were less likely to make the same assumption, with the percentage making the error at 38%, 21%, 15% and 3%, respectively. Kamii and Russell concluded children construct operational time a year later than Piaget suggested, between seven and eight years of age.

Zacharos, Antonopoulos and Ravanis (2011) investigated intuitive mathematical processes of Greek children and the intervention of social exchange within a teaching interaction. Twenty children from two Greek kindergartens were presented with pre-test, intervention and post-test questions regarding measurement and capacity. The children were given three scenarios to determine the capacity of a container. The children were told a story about a farmer needing to feed his chickens and different sizes of containers necessary to feed varying numbers of chickens. Intuitively, the children chose the tallest container, thinking it would hold the most. During a teaching intervention, all the children were divided into small groups of four or five and shown how the farmer could determine the capacity with small, equally sized cups. The children then worked with their peers to determine a solution. Through their dialogue, the children came to an understanding of the measurement process. A week after the intervention the children were given a post-test with the same scenario but with containers of differing shapes, prompting disequilibrium in their mathematical thinking. As a result, many of the children's intuitive thoughts were enhanced by reasoning, based on the earlier intervention, prompting them to make accommodations to their initial thinking. The researchers proposed the social exchange with their peers during the intervention contributed to the justification and development of children's mathematical thinking, moving them forward from math intuition to knowledge.

Summary of Mathematical Thinking Literature

Though the above studies point to the advanced mathematical thinking of young children stemming from math play and intuition, the majority of the studies were based on teacher-guided experiences of children. Teacher intervention and facilitation targeted specific mathematical concepts the researchers sought to understand. Further, the studies that were conducive to a natural evolution of mathematical concepts were conducted with children ranging in age from one to four years-old, of which there was a significant difference in mathematical and language abilities.

The exploration of how young children communicate their mathematical processes has been limited. The communication of mathematics provides access to the internal mathematical knowledge of children. Exposing young children's mathematical thinking is necessary to fully understand young children's mathematical knowledge.

Vygotskian Theory

The thoughts within the mind go through a process before they are communicated through language. There is a back and forth exchange of thoughts and words before they are given form. Aligned with Piaget's aforementioned theory, Vygotsky suggested that thoughts make connections and establish relationships between things, constructing a reality within the child. After undergoing several changes, the thoughts become reality and are expressed through language (Vygotsky, 1962), producing verbal thought.

Vygotsky described the journey of verbal thought as a transition through various planes or dimensions and as a collaboration between thought and words that is not easily communicated (Vygotsky, 1962). The process begins with the motive to provoke a thought, initially a desire, need, interest or emotion. Once the thought is shaped, there is an internal speech, a monologue within the mind. During the monologue, words and their meanings are formulated, finally ending in an expression of language. The process may not always be completed but may stop at any one of the planes (Vygotsky, 1962).

Vygotsky suggested verbal thought, with its varying stages, was a function of both cognitive and communicative ability. He described this inner speech as a fluctuation between thought and word, though it may, at times, be external until young children are capable of constructing the cognitive processes without vocal expression (Vygotsky, 1962). Vygotsky described it as a problem-solving tool young children use to manipulate objects and control their actions. For a young child to solve a problem he or she needs to talk through the process to arrive at a solution. Through their language, young children show flexibility in their problem-solving as they begin to link past experiences and actions to current situations (Vygotsky, 1978).

Vygotsky further explained the idea that higher mental functions are socially formed and culturally influenced (Vygotsky, 1978). As children engage in problem-solving, their actions become fused to their speech. In verbal exchanges with others, children are externalizing their thinking and communicating their understanding of a shared experience. Through this process, children's understandings and thoughts can be challenged and, eventually, reconstructed to new ideas.

Language serves as a conduit between thoughts and understandings of a child, externalizing information for the listener. Listening to young children communicate their mathematical processes, both to themselves and to others, can reveal the mathematical thinking occurring within. Much of the research around mathematics and communication has been restricted to older children and adults, though the link is also relevant in the early years. Encouraging children to explain their mathematical thinking has been shown to be the most powerful strategy to understand their mathematical thinking (Dunphy, 2010; Charlesworth & Leali, 2012).

Math Talk

Engaging young children in conversations about their mathematical thinking would inform teachers and guide their teaching approaches pedagogically. Anthony and

Walshaw (2009) reviewed studies of preschoolers that suggested peer interactions and provocations from the teachers increased children's knowledge of mathematics. Appropriate play that promoted shared learning resulted in children's ability to communicate their mathematical thinking through discourse with others. To develop mathematical thinking, children need the freedom to construct, compare and experiment. The teacher's role is to facilitate this process by creating an environment conducive to exploration (Lesh & Doerr, 2000). Both teachers' and children's math communication are necessary to promote mathematical thinking and learning.

Teachers' Math Talk

The early childhood teacher serves as a coach for young children in every aspect of development. Both cognitive and communicative mathematical exposure influences the knowledge children gain in the classroom settings. As teachers expose children to new concepts and ideas, their use of language serves as a guide for children's mathematical development, which includes math talk. Studies have examined teacher strategies that stimulate math talk and prompt collaborations among children to discuss and draw conclusions in mathematics.

Stimulating math talk. Cooke and Buchholz (2005) chronicled a kindergarten teacher's strategies in promoting math language in the classroom. The teacher worked with 20 children in a low-income area in a southern city. A three month observational period resulted in the researchers identifying six informal strategies implemented by the teacher. These included: connecting everyday routines to math concepts; asking children open-ended questions about their play; and providing opportunities of self-expression by the children. The observations supported the importance of mathematical communication and its role in stimulating mathematical thinking, an example of Vygotsky's verbal thought.

Klibanoff et al. (2006) probed the impact that teachers' use of math talk had on preschool children's mathematical knowledge. Preschool teachers from 26 classrooms of children categorized as high, medium or low socioeconomic status were recorded during an hour of instructional time. Recordings, which occurred during and immediately following whole group time, were transcribed and indicated teachers' mathematically relevant comments varied from 1 to 104 comments. One hundred and forty-eight children in the selected preschools were assessed on their mathematical knowledge at the beginning and end of the school year with a 15-item instrument developed by the researchers. An analysis of the teachers' math talk and children's math knowledge revealed a significant relationship. Despite the differences in the socio-economic status of the children included in the study, children's math progress was highly influenced by teachers' math talk. The study highlighted the significant impact teachers' use of math language can have on young children's math acquisition, further supporting Vygotsky's link between thought and language.

Rudd, Lambert, Satterwhite and Zaier (2008) expanded this line of research as they examined the specific types of math talk early childhood teachers use in high quality classrooms. The study, which included both qualitative and quantitative data, was conducted with 11 degreed teachers at a university child development center who were observed and recorded for forty hours over a four week period. The recordings were then coded by specific categories of mathematic concepts. The analysis of the data indicated teachers spent over 70% of their math talk on basic skills like number and spatial awareness, and less than 1% on operations, patterns and display, the higher level skills. Observations also revealed a lack of planned math activities to develop concepts. Researchers concluded teachers need guidance in providing appropriate mathematics activities through language use to stimulate children's mathematical learning and language.

Mathematical collaborations. In mathematical development, the teacher creates a setting and play opportunities to provoke children to explore, question and seek out solutions. Linder, Powers-Costello, and Stegelin (2011) examined strategies commonly used by teachers of young children and recommended additional approaches to mathematics in the early childhood setting. Teachers, acting as facilitators of knowledge, work collaboratively through open-ended questioning to create meaningful contexts for mathematics. The authors proposed Reggio Emilia inspired approaches to mathematics were most effective in children's acquisition of concepts. Each of the strategies provoked children's discussions and explorations. Examples of mathematics tasks were presented to reflect the open-ended questions asked, such as explaining how a collection of items from the outdoors were sorted. The questions shared in the article were designed to encourage children to examine and discuss their mathematical thinking.

Jung and Reifel (2011) conducted a qualitative case study of a kindergarten teacher's implementation of effective mathematics instruction through children's communication using a Vygotskian lens. Focusing on socio-constructivism, the researchers suggested children construct their understandings through talk, social exchange and shared meanings. The teacher in the study, a Texas public kindergarten teacher with 20 years of experience, was videotaped over a 12 week period and, during the weeks, was also interviewed on four different occasions. Additional documents were collected, including mathematics curriculum, school district mathematics guidelines and student work. After an analysis of the information, two themes were established: the teacher's beliefs and experience and public school constraints. The use of authentic opportunities to engage children in reasoning and mathematics were imperative in creating dialogue among and with the children. She created an atmosphere of collaborative, shared learning, which encouraged children to construct mathematical knowledge through verbalization. The teacher also asked open-ended questions to prompt development of mathematical concepts.

Björklund (2012) suggested teachers' communication and interactions with young children are imperative to deepen the children's understandings of mathematics. As the educator listens and follows the intentions of children's actions and communication, he or she can advance the children's mathematical thinking. Further, children's math talk will facilitate their thinking and rethinking of strategies employed in applying mathematics in their experiences (Jung & Reifel, 2011).

Children's Math Talk

Young children's social interactions reflect their internal processes and thinking. Their use of language allows insight into the mathematical thinking developing in their minds. The talk provides a conduit for expression of the unique understandings and interpretations of the individual child. Gaining access to the mathematical processes of the child creates a foundation from which the listener can assist furthering the development of mathematical thinking.

O'Neill, Pearce and Pick (2004) probed the relationship between narrative language abilities and future academic achievement of preschool children in a longitudinal study. Forty-one preschool children, ages three to four, were shown a wordless picture book and asked to tell a story to a puppet doll positioned next to the child. Through transcription of the narrative, the language was coded for several aspects such as length of utterances, conjunctions, vocabulary, and perspective shifting. Children's language was also assessed through an instrument designed to assess expressive and receptive language, the Test of Early Language Development (TELD). During the kindergarten year, the children were given the Peabody Individualized Achievement Test to determine academic achievement. The analysis of the data indicated a significant relationship between narrative abilities and later mathematical achievement. The researchers concluded narrative abilities directly influence later mathematical abilities.

Austin, Blevins-Knabe, Ota, Rowe, and Lindauer (2011) proposed that language skills predicted early math concept development. Within a Vygostkian framework, the study acknowledged the significant role language plays in young children's acquisition and understanding of mathematical concepts. Utilizing the Early Math Concept assessment, the Peabody Picture Vocabulary Test and the Bracken school readiness assessment, four and five year old children in both family care and child care settings were assessed. The researchers investigated which concepts, letter awareness or psychosocial skills, mediated preschool children's mathematical thinking. The children's receptive language, when mediated by one of the two concepts, was measured in relation to changes in the preschoolers' early math concepts development. The findings indicated that early math concepts were predicted by the children's receptive language significantly when mediated by letter awareness. The researchers concluded symbol systems like letters taught in tandem with early mathematics can positively influence both areas.

Sarama, Lange, Clements and Wolfe (2012) explored a preschool math curriculum, *Building Blocks*, and its impact on language and literacy skills. They hypothesized that the math curriculum would positively impact children's oral language development and letter recognition. They also cited NCTM's statement on mathematical communication and its importance to their cognitive understanding of the concepts. The study included an experimental and a control group of kindergarten children; the experimental group received the curriculum and teacher training while the control group used the standard district math curriculum. Applying the concept of mathematics in everyday situations, the children were guided in discussions in recognizing the concepts in various activities. The experimental group learned more math than the control group, based on the Tools for Early Assessment of Mathematics (TEAM). Further, the oral language of the experimental group, assessed through story retelling and answering inferential reasoning questions, significantly outperformed the control group on complexity of utterances in story retell. The researchers suggested the advantage may reside in the amount of language promoted in the *Building Blocks* curriculum, which helped children explain their mathematical thinking.

Summary of Math Talk Literature

The research surrounding math talk has primarily targeted the teachers' intervention and strategies to prompt children regarding mathematical tasks or the lack of mathematical language occurring in classroom settings. The children's math talk was examined through formal assessments of language and reviews of math curriculum. The natural math talk that occurs among children has been limited in the research, revealing the necessity for further research.

Summary

Logico-mathematical knowledge, as defined by Piaget, requires young children to recognize relationships between and among objects. This process is unique to each child and involves construction of ideas and thoughts. It is a deeper level of thinking that is necessary for the advancement of mathematical thinking.

The literature reviewed of young children revealed play as a natural expression of mathematical thinking. Math play provides a relevant experience to learn, extend and communicate the knowledge acquired. Children both construct and re-construct thoughts as they link them to their playful situations. Further, intuition, defined as a child's natural way of thinking, serves as a foundation upon which mathematical thinking develops (Kamii & Joseph, 1989). Children begin their problem-solving experiences with non-quantitative approaches which are challenged when inaccurate. The inaccuracy often results in children learning a new strategy with mathematical insight.

To understand the internal logico-mathematical knowledge of children it is necessary to interpret their math talk. As Vygotsky (1962) explained, language provides the realm from which children communicate their thoughts. The verbal exchange that occurs between the child and adult or child and peer not only shares the verbal thoughts but can incite revisions in knowledge.

Communication of mathematical thinking allows others to understand and create experiences that can bring about more advances in their thinking. Research has shown the teacher's use of math talk exposes children to new concepts and ideas that can positively influence children's mathematical thinking. Mathematical language used by the teacher stimulates children's mathematical thinking and collaborative activities. As children engage in math talk they not only explain their processes to the listener but also to themselves, moving the thoughts to words. The math talk results in more advancement in mathematical thinking, as it impacts the teacher's provocations and children's explanation of their thinking.

CHAPTER III

METHODOLOGY

Introduction

Mathematical concepts are a natural part of young children's lives and serve as a vehicle to numerous opportunities for exploration and interaction with others. The evolution of mathematical thinking in young children has not been explored extensively in the study of early mathematics. To gain some understanding of this process, it is necessary to investigate the verbal communication surrounding mathematical concepts. This study provided insight into children's use of math talk and its role in mathematical thinking. The researcher focused on the mathematical communication among children as well as the self math talk during children's play. This phenomenological qualitative study sought to answer the following research questions:

1. How do preschool children use math talk?
2. How do preschool children communicate changes in their mathematical thinking?

Research Design

Phenomenological research explores the direct experience of a phenomenon (Bernard & Ryan, 2010) and is not merely a recollection of actions but of experiences that focus on the possible meanings of the lived experience of the individuals or a probable explanation of the "nature of a certain human experience" (van Manen, 1990, p.37). The lived experience is the immediate, natural activity that can only be realized through reflection and phenomenological research allows the outside world to grasp the importance and magnitude of the lived experience (van Manen, 1990).

Phenomenology was an appropriate method in conducting this research study as it seeks to describe and interpret the experiences as they are lived. Phenomenology does not merely provide an understanding but a clarification of the experience (Danaher & Briod, 2005). Edmund Husserl, the forefather of phenomenology, described it as a science based in vivid and detailed imagery that seems visible (Bernet, Kern, & Marbach, 1993, p. 78). Further, the meaning of the experience is determined by the consciousness of the individual and the content where it was situated.

Phenomenological research with children is intended to expose the essence of what it means to experience something as a child. The adult's view is suspended to search for the meanings of the experience as it relates to the child. It is not an inquiry into a world the adult professes to understand or explain. Rather it is an experiential description that is unique and can deepen the humanistic vision of the child's lived experiences (Danaher & Briod, 2005). Because the adult can no longer access his or her childhood experiences outside of the experiences across the lifespan, phenomenological research with children is a necessity (Welsh, 2013).

Phenomenology guided this study in understanding how preschool children experience the phenomena of mathematics through their language. The preschool children who were the focus in this study were too young to discuss how they use math talk or reflect on previous lived experiences. Instead, the researcher entered the experience as it was lived out as a participant observer (Fine & Sandstrom, 1988). This approach served as a catalyst in understanding the use of communication that occurs within math talk.

Researcher's Perspective

I have been in the field of early education and care for over 15 years as a classroom teacher, mentor, and facilitator of teachers' professional development. I have a Master's degree in elementary education with a specialization in early childhood. As a classroom teacher, I taught kindergarten and pre-kindergarten for many years and exposed my students to various mathematical activities beyond the limited suggestions in the curricula. In doing so, I was fascinated with the children's acquisition of mathematical concepts evident in their play and interactions.

After several years in the classroom, I became a mentor to pre-kindergarten teachers in Head start, public school district and child care classrooms. This experience revealed the limited mathematical activities teachers intentionally made available to children. Noticing this deficiency, I made an effort to share the importance of mathematical thinking in young children and how much more they were capable of understanding. My fervor for mathematics rarely translated to the teachers despite my modeling and coaching on early mathematics. These instructional experiences with early childhood education piqued my interests in children's early mathematics and language development. Hence, I explored the topic, mindful of the demands of a qualitative researcher and aware of my responsibility as the research instrument. Further, I understood the need to bracket my perspectives and apply reflexivity to my observations and findings.

Researcher as the Instrument

In qualitative research, the researcher is the instrument used to gather information (Patton, 2002), requiring the researcher to be adept in observing behaviors, not only with the eyes but with every part of one's being. As the instrument for data collection, the researcher collects background information on the topic of study and understands the potential participants through some interactions to build rapport (Janesick, 2000). Janesick describes the researcher as a dancer, applying both structure and improvisations based on the demands of the field. The researcher must also be competent in piecing together data in complex situations (Denzin & Lincoln, 2000), allowing the organization of data to be shifted and changed as needed to completely interpret the research. The researcher must be able to employ the strategies and methods of qualitative research, and if none are sufficient, develop techniques to address the needs (Barrett, 2007).

In preparation for this research, I examined the previous works surrounding mathematics and language to deepen my understanding and knowledge. This examination of research allowed me to frame the structure of the methodology and prepare for the field work. I recognized there would be unexpected occurrences in the field site and was equipped to adjust to the needs and changes of the participants in the study. I engaged the children with questions to stimulate the math talk throughout the observations and followed their responses to pose additional questions.

Bracketing

The researcher, to remain credible, must be capable of bracketing, defined as an awareness of one's perspectives throughout the research study (Fischer, 2009). The researcher shelves his or her perspectives as much as possible to diminish the impact they could have on the information observed and collected. Bracketing infers the researcher holds up the phenomenon, or focus of study, for close inspection of all the data collected (Janesick, 2000). This creates a situation where the data can be interpreted to define the meanings and essential elements of the phenomenon.

The research required me to bracket my knowledge and passion for early mathematics during the research to refrain from judgment of the teachers' and other adults' communication of mathematics with the children. I attempted to understand each component of the data collected equally and its meaning to the children. Bracketing my perspective assisted me in examining the phenomena of math talk.

Reflexivity

To fully interpret the data collected, the researcher must engage in reflexivity, reflecting on self as both an inquirer and responder (Lincoln & Guba, 2000). Each individual is a compilation of multiple selves, all of which are subjective. A researcher may be a parent, a student, and a teacher, each of which shapes experiences and interpretations. Reflexivity is a deconstructive exercise intended to remind the researcher of the multiple influences from his or her life history (Macbeth, 2001). As the researcher identifies each of the selves, he or she can consider how each one influences the understandings and thoughts during and after the data collection and analysis.

My experiences and education in early childhood education and development have allowed me to serve as a mentor, teacher, advocate and student of early education. Each of these roles shaped my views and perspectives, resulting in a constructivist outlook. Recognizing my subjectivity equipped me to deconstruct each role to acknowledge how each impacted my interpretations and articulate these influences to the readers of the study, providing the reader with a definitive image and view of my subjectivity.

Population

Field Site Description

The site in this study was a child development center in the south central region of the United States that served children from three weeks to five years of age. The center, in operation since 1993, was operated by a non-profit organization in a metropolitan community. The center was recently accredited by the National Accreditation Commission (NAC) for early care and education programs. NAC offers a comprehensive quality improvement system that has recognized and awarded 1,500 early education programs across the United States and overseas for their commitment to quality programming. It was the intent of the center to become a demonstration site for other early education professionals. With observation booths in each of the seven classrooms, the center's design allowed students and professionals an opportunity to observe best practices in early childhood.

Each of the classroom teachers in the center had a Child Development Associate credential. The teachers were also required to participate in numerous hours of professional development each year, exceeding the state requirement. The teacher-child ratio in the classrooms were lower than required, which allowed for an enhancement of the children's experiences. The targeted classroom had a ratio of 1:6 though the state only requires a ratio of 1:11 (Texas Department of Family and Protective Services, 2014, p.71). The lead teacher in the focus classroom had been with the center for two years, with over fifteen years of experience in the early childhood field.

The curricular focus of the center was to create a quality environment supporting development of children, socially, emotionally, physically and cognitively. The curriculum in the preschool classrooms was aligned to the *Texas Pre-Kindergarten Guidelines* (Texas Education Agency [TEA], 2008) and the *Little Texans Big Futures,* the early learning guidelines for infants, toddlers, and three year olds (Texas Early Learning Council, 2013). The teachers also focused on individualizing instruction to meet the needs of each child.

Participants

Ten children in the transition classroom, ranging in age from two years and nine months to three years and eleven months, participated in the study. The site and classroom were chosen as a convenience sample, as the researcher had an established professional relationship with the center. The children in the participating classroom transitioned to the classroom at the end of August 2013 and remained in the classroom throughout the school year. These children had not yet received formal mathematics instruction, though experiences outside the classroom likely influenced the children's math talk and interactions. This provided insight into the logico-mathematical processes involved in the children's construction of mathematical thinking without the contamination of formal mathematical language and understandings. The interactions with the teachers were not considered in this study, as the focus was on children's math talk.

The children in the study ranged in language, mathematical knowledge and social skills. The roles of the children were unique in the classroom and varied based on the experiences of the day. To outline the characteristics of the participants in a study Miles, Huberman and Saldaña (2014) propose a role-ordered matrix chart can be appropriate. The chart outlines the behaviors and details that describe each participant. Below is the role-ordered matrix chart of the children (Table 1). Each child's name is a pseudonym to protect their identities.

Table 1

Role Ordered Matrix of Participants

Child Code Names	Age (year and month)	Enrollment Status	Math Strand commonly referenced	Purpose of Math Talk	Means of Communicating Changes in Mathematical Thinking
Amya	3.4	Full time	Numbers Geometry Measurement	• Directing and Protecting the play classroom rules	Restate idea
Bianca	2.9	Full time	Numbers Measurement	• Reinforcement classroom rules • Making Comparisons	Teaching/Sharing Knowledge
Cary	3.3	Full time	NO	NO	NO
David	3.3	Part time	Numbers	• Descriptions and Request	NO
Eric	3.11	Part time	Numbers	• Directing and Protecting the play	NO
Fiona	3.6	Full time	Numbers Measurement	• Manage and access materials	NO
Gabby	3.4	Part time	Geometry Numbers	• Manage and Access Materials	NO
Helen	2.9	Full time	Numbers	• Declarations	Teaching/Sharing Knowledge
Ivy	2.9	Full time	Geometry	• Descriptions and Request	NO
Jean	3.10	Full time	Numbers Geometry	• Manage and access of materials • Description and Requests	Teaching/Sharing Knowledge

Verbal Portrait

The research site, a classroom of three-year-olds, was arranged to promote a school family atmosphere where children feel safe and welcome. This theme was evident through the structures of the classroom and the management system in place. Upon entering the classroom, children would pause at the attendance chart, acknowledging their arrival at school by moving their nametags from the home picture to the school picture. The children then visited their cubbies, labeled with their names and pictures, to place personal belongings like backpacks and coats.

Two rectangular tables were near the cubbies where the children gathered for family style meal times. With the parents' assistance, children washed their hands then escorted their parents to the door to say goodbye. The children then joined their peers and teachers at the tables for breakfast. After completing breakfast, children visited the different play areas of their choice until the teacher was ready to begin the instructional day.

After about ten minutes, a song would begin, signaling the children to put away the toys and join the teachers at the large carpet area for whole group time. The group time involved songs about the children's names, partner songs, and other opening rituals. After a review of the daily schedule, the classroom job chart was discussed and reviewed to remind children of their responsibilities, which included tasks such as weather person, lunch helper, and flag holder. The children were then dismissed to engage in the play areas, referred to as centers.

The centers available in the classroom were dramatic play, construction, art, library, writing, science and math. A small rectangular shelf served as a boundary between the whole group area and the centers that were arranged throughout the classroom. Each center was labeled with a sign stating the center name and Velcro dots below the sign for children to place their nametags, limiting the number of children in the center. The teacher had used the system with the children who had been in the classroom for most of the school year. Most centers had low shelves that created boundaries to define the spaces and to store materials. The materials available in the centers were exchanged frequently, based on the topic of study and the children's interest. The children were allowed to freely move through the centers. The math center had manipulative materials on a shelf, such as counting bears, sorting mats, number puzzles and plastic shapes. In front of the math center was the library, which was arranged with several books on a shelf, stuffed animals and pillows for the children to sit on when looking at the books. Beside the library was a writing center that had shelves on two sides enclosing the space, one shelf opened towards the table and the other faced the construction center on the other side. A table with two chairs was positioned in the middle of the center and pencils, crayons, paper and letter puzzles were common items on the shelf. Behind the writing center was a large open area for the construction center with shelves of blocks, trucks, linking logs and other toys for building. The dramatic play center was located beside the construction center, equipped with child size furniture including a stove, refrigerator, table and chairs, as well as a shelf with clothes, dolls and dishes. This center frequently changed based on the topic of study in the classroom. The children engaged in role play and dress up when playing in the center, sometimes on the topic of study and other times not, dependent on their imagination. On the other side of the classroom there was a science center with a small table and chairs as well as rocks, dried plants, and science tools like magnifying glasses and magnets. A shelf separated the science from the art center, which had an easel and paint, crayons and paper on the shelf.

Center time was free choice each day and the teachers occasionally worked with small groups on a specific activity or engaged with children's play in the centers. If a child had a difficult situation arise, the teachers intervened to give guidance and foster children's self-regulation with strategies to calm themselves. In addition to this support, children could choose to visit a safe place, which was a cozy corner in the room with pillows, pictures, dolls and an emotions chart for children to interact with to calm themselves.

After center time ended, children would return to whole group time to share in a story, typically focused on the topic of study, and read by the lead teacher. The children asked and answered questions during the reading, remaining engaged throughout the short picture book. At the conclusion of the story the children and teachers prepared for outdoor play and learning in the space outside, exiting through the back door of the classroom. During the 30 minutes outside children engaged in free play, riding the tricycles and scooting toys as well as playing on the slides and play structures available. Returning inside, children prepared for lunch with restroom breaks, hand washing and the helpers setting the tables for their peers. A two hour rest time followed the lunch wherein each child gathered his or her blankets and would rest on the cots laid out by the teachers. When children were awakened, the day began again with restrooms and afternoon snacks and another whole group time, which was focused on a story. Children were dismissed again to center time to engage in playful interactions and visit centers they may not have visited in the morning or revisit favorite centers. At the end of the day, the lead teacher departed saying goodbye to each child and an afternoon teacher arrived to complete the day. As the children began to depart they moved their nametags to home on the attendance chart. As the number of children decreased, the teacher departed, leaving the afternoon teacher to end the day with children.

Data Collection

The data sources gathered in this phenomenological study included participant observations, field notes, transcriptions of audio and video recorded math talk during center free play and photographs of the classroom environment. The combination of data sources was elected to illuminate children's math talk and result in a triangulation of data that strengthened the study (Patton, 2002).

The data was collected one to three hours each week over a period of eight weeks and each observation session occurred during center time, which was scheduled for 30 minutes in the morning and 30 minutes in the afternoon. The researcher began the observations during the morning and afternoon times of the day but found the afternoon sessions limited in discourse among the children. Due to the limited discourse, the researcher revised the times of observation to the early morning free play, which occurred as children would finish breakfast and could access only half of the centers, as the teacher was concerned about the length of time it took to straighten up some of the centers. The second observation session occurred after the opening circle time, the regularly scheduled morning center time, at which time all centers were available to the children.

The researcher recorded field notes to document the interactions after each observation day, or, when possible, during the observation. The field notes were an opportunity for the researcher to document specific information that was relevant to the classroom climate and interactions. Days when the lead teacher was not present affected the adherence to classroom rules and routines, as the children took full advantage of those unaware of all the classroom expectations. With the abundance of transcribed data, these notes were necessary to establish an extensive picture of the children's interactions.

Participant Observation

To conduct qualitative research with children, it is important for the observer to establish a personal relationship with children (Browning & Hatch, 1995). Specifically, to become a participant observer, the researcher needs to spend time interacting with the children participating in the study while following their lead. Waiting for children to approach permits them to decide when and how the relationship or friendship will develop.

The researcher was a participant observer in the classroom throughout the study. Participant observation, as described by Bernard and Ryan (2010), occurs when the researcher and the participants have an established rapport. Based on this description, the researcher in this study established herself as a participant observer over the course of the school year. As a mentor in the field site, the researcher visited the classroom at least once a month to facilitate the teachers' professional development through modeling, coaching and discussions. In doing so, the researcher had several playful interactions with the children in the classroom. Both the children and the teachers were familiar with the researcher and seemed comfortable with her in the classroom, as it was also a regular component of the mentoring role. The frequency of the researcher's professional classroom visits allowed her access to the culture of the classroom and the children.

An imperative component in qualitative research is being in the classroom, which allows the researcher to observe the children and record field notes on interactions and conversations of the children (Patton, 2002). During the observations, the researcher focused on the mathematical communication occurring during the center time by interacting with children and asking provocative questions to stimulate the math talk.

Provocation refers to listening to children talk and creating a situation that provokes additional thought and action (Fraser & Gestwicki, 2002). Though often referred to as a strategy common in Reggio Emilia approach, provocations are commonly used in education settings to provoke children's thinking. Provocations can involve the classroom environment and materials made available to children. The researcher provoked children's exploration and expanded their math talk.

Provocations of math talk occurred with both closed and open-ended questions from the researcher. Questions included:

Are there enough squares for Gabby to use?

How many links do you think we need to add?

How much does the shirt cost? Do you have enough money?

The children's responses and comments prompted additional questions to focus the thinking and dialogue around mathematics. Through interactions with the children, the researcher noted the varying language abilities of the children and modified questions based on these abilities. As such, the researcher tended to ask more closed questions to children with less language and open-ended questions to those with more language.

With extensive knowledge of early childhood and early mathematics, the researcher played and interacted with the children to focus on the five mathematical strands set forth by the *Texas Pre-Kindergarten Guidelines* (TEA, 2008), which include counting, number operations, measurement, classification/data analysis and geometry. Some conversations did not lend themselves to very much mathematical concepts, therefore many other comments were involved to facilitate the natural flow of conversation.

Field Notes

Field notes, according to Patton (2002), are fundamental when conducting qualitative research. It is a platform wherein the researcher records everything he or she believes is noteworthy. The field notes provided details of the experience of the participants observed. The field notes also included the researcher's interpretations and insights into what was occurring. It was a record of what the researcher observed through listening, watching and interpreting during the process of data collection (Groenewald, 2004). Field notes prompt the researcher to clarify, in his or her terms, each of the observations conducted.

The field notes assisted the researcher in understanding the lived mathematical experiences of the children observed. Wolfinger (2002) offered a comprehensive approach to field notes, which entails thinking sequentially about the actions observed. He opined noting the first and last statements of an interaction will allow the researcher to recall events in the order in which they happened, increasing the accuracy of the field notes. The researcher made notes of how the interactions with children began and evolved during the observations.

Video Recording

Communication involves numerous aspects, all of which are important to interpret a communicative exchange in its entirety. Video of the children's math talk proved to be an invaluable source of data that allowed the researcher to collect both visual and audible communication that may have been missed in the researcher's observations. Video recordings can reveal the interactional patterns, as subtle as they may be, that may be dependent on the context and the participants involved (Walsh et al., 2007). Further, video recordings of the classroom activities may make the researcher privy to conversations that may or may not be directed to the researcher (Patton, 2002). Video recordings also allow the researcher to replay the sessions recorded as frequently as needed to begin to see beneath the surface of the interactions to analyze and interpret the sessions thoroughly (Björklund, 2010).

Though there are numerous benefits to collecting data through video, some challenges are apparent (Walsh et al., 2007). The observed video could mislead the viewer in accepting the face value of the social interactions or the context of the interactions may be missed. For example, two children engaged in a dispute in the morning could prompt a negative interaction in a social exchange later in the day. To overcome these challenges, the researcher was a participant observer and was able to capture the nuances of the classroom climate.

A small video recorder was positioned in various areas in the classroom, wherever the researcher noted the children's social exchanges. Further, the video recorder was placed on a small stand, which allowed the researcher to engage with children without the obstruction of handling the equipment. Though the children were initially interested in the recorder and stand, the novelty quickly dissipated as children went about their play.

Audio Recording

Audio of the children's math talk was collected through the use of the video recording, extracted from the video to allow for separate analyses. The audio allowed the researcher to concentrate on the verbal discourse outside of the non-verbal interactions that were reflected in the videos. Review of the transcribed discourse allowed the researcher to attend to the fine distinctions of the word choices and vocalizations of the children, which deepened the understanding and interpretations of the interactions.

Photographs

Photographs can offer insight to deepen the understanding of the research study and procedures applied (Patton, 2002). The researcher created still photographs of the classroom setting from the videos. The materials available to children were also photographed to assist in the descriptions of the classroom observations. The classroom environment served as a platform wherein cognitive experiences were stimulated and, therefore, offered invaluable information on the lived experiences of the children in the study. The photographs were an additional source of meaning-making regarding the classroom (Dicks, Soyinka, & Coffey, 2006).

Protection of Human Participants

The research study met the requirements of the Protection of Human Participants and obtained approval from the Institutional Review Board (IRB) at Texas Woman's University. Upon approval from the IRB, the researcher contacted the leadership of the child development center that was the site for the research and provided a detailed description of the methodology of the study. The center leadership was invited to a meeting with the researcher to answer any questions. After receiving approval from the center, the parents of the children in the desired classroom received a letter describing the methodology of the study and a consent form. The letter included all possible risks to participation in the study as well as the benefits of participation. The parents were invited to attend an informational meeting to allow the researcher to address any concerns and collect the consent forms. The researcher also explained declination to participate in the study could occur at any time during the study if so desired.

The observational notes and video recording transcripts collected during the study were kept in a locked file cabinet in the researcher's home office. The children's anonymity was not compromised as they were each given a pseudonym when referenced in the transcripts and throughout the study. The video recordings were only made available to the peer reviewers and the faculty advisor.

Process of Analysis

The analysis of qualitative research looks for the meaning or meanings of the data collected (Bernard & Ryan, 2010). The analysis was intended to offer meaning of the observed phenomena, math talk, as it was observed and recorded. Conducting data analysis involved organizing and questioning the data to uncover patterns, themes, and relationships to clearly communicate findings to others (Hatch, 2002). The process of analysis, according to Hatch, ensues from the very beginning of data collection at an informal level and continues throughout the research study. As such, the procedures that were employed for this analysis began at an informal level with transcriptions of the video and audio recordings, as well as reviews of the field notes, occurring simultaneously throughout the data collection process. In addition to the informal analysis, analytic memos, coding and discourse analysis were also applied in the analysis procedures. *NVivo 10* software was the vehicle wherein the data collected was sorted and managed throughout the study. A thick description of math talk among preschool children provided a detailed view of the research to assist the reader in locating the context of the research findings.

Procedures

The analysis began at the onset of data collection with viewing the video and audio recordings collected and reading through the field notes documented. At the end of each week of data collection, the video and audio recordings were transcribed by the researcher and reviewed in conjunction with the field notes. During this process, the researcher made notes of plausible interpretations of the data as comments within the margins of the transcripts.

The qualitative software *NVivo 10* was utilized to organize and manage the data collected to facilitate the data analysis. *NVivo 10* was simply a means of gathering, storing and organizing the data. The analytical determinations were completed by the interpretations and translations of the researcher. The researcher added analytic memorandums throughout to assist in following the path of the compilation of data and the researcher's thoughts.

Analytic Memos

Saldaña (2009) defines analytic memos as a space where the researcher can be reflective on the information observed or blog about one's thoughts. Doing so allows the researcher to analyze findings throughout the study, as they can be written in the process of data collection as well as after. The compilation of the memos can suggest codes and themes occurring in the process of the field research. Saldaña (2009) suggests memo writing is an opportunity for the researcher to reflect on numerous ideas, such as the research questions, theory, emergent themes and personal dilemmas during the research.

The researcher wrote analytic memos on the data, which focused on the research questions, in light of the data, as well as the potential links among themes observed. Writing the memos throughout the research assisted in identifying codes and themes in the data collected. The researcher recorded analytic memos while thinking critically about the data collected.

Coding

Data collection in the research study resulted in an abundance of information from transcripts, field notes, and other data sources deemed important. Coding is a procedure for organizing the data and discovering the underlying themes throughout the data (Auerbach & Silverstein, 2003). It requires the researcher to interpret the data collected to uncover basic, plausible meanings of the compilation of data sources (Saldaña, 2009). The coding can include both pre-set or *a priori* codes and emergent or inductive codes (Fereday & Muri-Cochrane, 2006), both of which are beneficial, depending on the goal of the study; this study employed both.

First cycle coding. *A priori* codes were initially established to examine the children's math talk during the analysis. The *a priori* codes used were derived from the five mathematical strands postulated in the *Texas Pre-Kindergarten Guidelines* (TEA, 2008), which are counting, number operations, geometry, measurement, and data analysis. During the first cycle coding of the transcripts, the researcher analyzed the references to each strand evident as the children engaged in math talk. After analyzing the strands, only four of the five mathematical strands were evident in the math talk, therefore the researcher refined the codes by renaming and creating sub-codes. Table 2 lists the *a priori* codes and definitions of each.

Table 2

A Priori Codes, Sub-codes and Definitions

Codes	Definitions
Numeracy	Counting and labeling the quantity of items and people Making quantifications statements using more, too much, all, a lot or none to approximate the amount of objects or people without actually counting
Geometry	Shape naming and recognition of basic shapes Spatial awareness- understanding spatial words (ex. up, down, in, beside)
Measurement	Identifying sizes, length and capacity; making comparisons of objects (ex. big, tall, small, little)
Classification	Sorting and classifying objects that are the same or different

Descriptive coding was applied inductively to identify elements of the data and make connections to create an understanding of the whole phenomena (Hatch, 2002). Descriptive coding assisted the researcher in identifying the topics and describing what the children were discussing in the math talk. This coding highlighted the basic topics of discussion in selections of the transcriptions and data sources and was helpful in answering general questions.

The play contexts were coded to further analyze the children's math talk, highlighting specific types of play that facilitated the math talk. The coding revealed contexts of play, which involved the settings and play scenarios the children engaged in. Two of the play context, the ice cream shop and the camping trip, were enhanced by the teacher with the inclusion of specific props and materials. The other contexts of play were motivated by the children's play, which the teacher followed and incorporated materials to further the children's play. Table 3 identifies the codes and a brief explanation of each.

Table 3

Context of Play Codes and Explanations

Context of Play	Explanation
Family Play 	Dramatic play center filled with home and family props that prompted play that included birthdays, cooking, driving and shopping
Ice Cream Shop 	Dramatic play center became an ice cream shop with play money, ice cream, a cash register and an ice cream shop sign
Camping Trip 	Dramatic play center became camping site, beginning with children's pretend play and later included a tent and tree designs on the wall
Building Things 	Construction, math and science center were filled with manipulatives such as blocks, magnetic shapes, and Legos where children engaged in creating/constructing

Second cycle coding. During the second cycle of coding, verbal exchange coding was applied, which has been described as a verbatim transcript analysis and reflection of the speaker's meanings (Saldaña, 2009). The researcher focused on the dialogic form of exchange, one of the five forms of communicative exchange described by Saldaña. This phase of coding equipped the researcher with additional information and incorporated discourse analysis.

After analyzing the mathematical strands and the context of play, the researcher examined each individual child's math talk and exchanges with his or her peers, the teacher and the researcher as participant observer. In doing so, themes began to emerge regarding the intent of the children's math talk. The researcher cross-referenced each child's talk with the first two sets of codes revealed in the first cycle of coding through a cross matrix query in *N Vivo 10*, which led to the discourse analysis.

Discourse analysis. The discourse analysis assisted the researcher in exploring the phenomena of math talk. Gee (2011) defined discourse analysis as a study of language as it is used, which includes the intent of the speaker. Discourse analysis investigates the possible connections regarding the meanings and connotations of the spoken text (Alldred & Burman, 2005). This level of analysis can provide insight into the position of power that is apparent for the speaker at the time the discourse was captured, as the position may change based on the participants engaged in the conversation (Alldred & Burman, 2005). The power was occupied by different children, depending on the participants, context and intent of the children involved in the math talk.

Gee (2011) suggested language connects saying, doing and being together to articulate the complete message. He proposed 27 tools to apply in discourse analysis. Each tool is “a specific question to ask of the data” (Gee, 2011, p. x) while investigating the discourse. This study applied the *Doing Not Just Saying* tool, which Gee defined as what the speaker is trying to do, not just say, and understanding that may involve multiple intentions (Gee, 2011). For example, a teacher may ask a child a question to ascertain the child’s knowledge, not to learn something new, as he or she already knows the answer. The analysis of the math talk, using the *Doing Not Just Saying* tool, revealed the themes and specific characteristics about each child’s mathematical discourse, communicative changes and level of savvy in communicating with others.

Thick Description

Qualitative research establishes its foundation with a thick description of the phenomena, a comprehensive understanding of the topic of study (Denzin & Lincoln, 2013). It is designed to encapsulate the thinking, social interactions and feelings of the participants and place in context (Ponterotto, 2006). Thick description not only includes the details of the study but also entails an interpretive element of the description. With this description, the reader is led to cognitively and emotionally enter the context of the research. The thick description of the study was intended to offer the reader a thorough picture of the daily mathematical experiences of the children in the study and share the basic tenets of the lived experiences observed.

Methodological Rigor

In qualitative research the researcher must establish integrity and credibility in the inquiry process, which can be achieved through triangulation of both data and analyses (Patton, 2002). This study triangulated the data by collecting field notes, video and audio recordings, and photographs, which prompts confidence in the study findings (Thurmond, 2001). The analysis was also a triangulation of analytic memos, *a priori* and inductive coding, and discourse analysis.

Since the researcher is the instrument in qualitative research it is important he or she reveal personal information to provide the readers with a clear view of the perspectives and viewpoints that could influence the credibility of the study (Patton, 2002). The researcher has been transparent in explaining her experiences in early education that shape her perspectives, with an acknowledgment of a need for reflexivity throughout the study. Further, the researcher has identified herself as a constructivist thinker impacted her processes and understandings.

Summary

This chapter has described the methodology applied in this phenomenological study of preschool children's math talk. The children's use of math talk was explored through the lens of a participant observer and a collection of field notes, photographs, video and audio recordings. The data sources resulted in a triangulation of data, intended to strengthen the study (Patton, 2002).

The researcher has shared her perspective, acknowledging the need for bracketing the data to reduce the information to what was clearly observed. She also recognized the multiple aspects of her life that influence her thoughts, which required her to be reflexive in noting her subjectivity. The analyses included both *a priori* and inductive coding, both of which were imperative in interpreting the data collected. Discourse analysis was applied to deepen the understanding of each individual child's use of the math talk and language in general. A thick description was included to provide the readers with the context wherein the phenomena of math talk will occur. Each of the components was collaboratively examined to understand how math talk was utilized among preschool children, resulting in specific themes that answered the research questions.

CHAPTER IV

DATA ANALYSIS

Introduction

The data analysis of this phenomenological research study is presented in this chapter. The chapter expounds on the math talk of preschool children engaged in free play in their classroom. The data collected during the study included transcriptions of the video and audio recordings, field notes and photographs of the classroom environment.

Jean Piaget's theory of cognitive development served as a key theory in the study, as he proposed the process of knowledge acquisition in young children (Piaget, 1950). When young children have mathematical experiences there is a level of both physical and logico-mathematical knowledge that evolves. The physical knowledge occurs when a child observes and discovers the properties of objects. This experience occurs outside the realm of an adult's guidance or input (Thomas, 2005). The logico-mathematical knowledge develops as a child manipulates objects and gains new information of the relationships between objects and the action on the object. Throughout the observations of the children in free play both types of knowledge were at work.

Lev Vygotsky's theory of social cognition was also complementary to the study as he described that communication prompts deeper levels of understanding (Vygotsky, 1962). The link between language and thought prompt a process for children to communicate their thinking. A child's thoughts undergo a series of changes prior to being verbally communicated. The study sought to identify the externalization of mathematical thinking through children's math talk.

The research questions that guided this study were:

1. How do preschool children use math talk?
2. How do preschool children communicate changes in their mathematical thinking?

In developing the study, the researcher elected to employ a phenomenological approach to capture the direct experience of the phenomenon of math talk in a preschool classroom. Phenomenological research seeks to explain the nature of the experience (van Manen, 1990). The researcher intended to deepen the understanding of math talk as it is lived and expressed among preschool children. Phenomenology research with young children is an attempt to suspend the adult's perceptions and seek the meaning of the phenomena, math talk, as it relates to the children.

Theoretical Framework

Two theories informed this study of preschool children's use of math talk during their free play. The first theory was Jean Piaget's theory of cognitive development, which guided the exploration of the children's knowledge construction and mathematical thinking. The second theory was Lev Vygotsky's social cognition theory, which informed the examination of the children's communication with others.

Piaget's Theory of Cognitive Development

Piaget's theory of cognitive development was a guiding principle in this phenomenological qualitative study. Knowledge is acquired through an internal process that is influenced by both external and internal stimuli. Three types of knowledge are connected to this internal process: physical, social and logico-mathematical (Piaget, 1970). This study focused on the physical and logico-mathematical knowledge.

Physical knowledge is the basis of children's understandings of properties of objects. As children observe objects they take note the explicit characteristics and add it to their knowledge base. When children begin to manipulate and experiment with objects their logico-mathematical knowledge begins to evolve. Logico-mathematical knowledge is the mental process wherein children identify relationships between and among objects (Kamii, 1982). It prompts a renewed, deepened understanding of the objects and the new data is added to their schema. Piaget suggested adults should observe the reasoning and reflections of children in their play experiences to better understand the children's knowledge construction (Piaget, 1970). Further, children should consistently be engaged in active discovery and exploration to promote their knowledge construction and reconstruction.

Vygotsky's Social Cognition Theory

Vygotsky's social cognition theory was also a principle that complemented this phenomenological study. The social cognition theory highlights the level of thinking that occurs in the back and forth exchange of language (Vygotsky, 1962). The dialogic interactions were analyzed with a focus on the mathematical knowledge expressed, exchanged and attained within the conversations among the children.

Vygotsky referred to the convergence of thought and language as verbal thought wherein children are able to communicate their mental activity (Vygotsky, 1962). Further, verbal thought is both a communicative and cognitive process that serves as a tool for children to solve problems. Through verbal thought children are capable of controlling their actions and guiding themselves in manipulations of objects.

Higher mental functions can be attained through the verbal thoughts exchanged with others (Vygotsky, 1978). The verbalization of thoughts pushes forward the development of deeper levels of understanding (Vygotsky & Luria, 1993). Met with the verbal thoughts of others, the thinking of the child can be enriched and accelerated to greater comprehension. Listening to the language exchanges of the children can reveal their thinking and the changes that occur as they are faced with opposing or challenging information from others.

Description of Participants

The participants in the study were preschool children, ages two years and nine months to three years and eleven months, in a classroom at a child care center in North Texas. With a full year range between the oldest and youngest children, there were varying language abilities and degrees of mathematical understandings among the children. The children operated within an informal mathematical understanding, though some showed more accuracy in applying and talking about mathematical concepts.

The ten children in the study, seven girls and three boys, were from various socioeconomic backgrounds, as the child care center accepts families receiving state subsidies to assist with child care cost. Seven of the children attended the center on a full time basis, Monday through Friday. The remaining three children attended two to three days each week. The language abilities of the children also varied and were not necessarily aligned to the age of the children. For example, Amya, Jean and Eric had the most language among all the children while Fiona at times was unintelligible in her sentence structure. The role-ordered matrix (Table 1) shows the basic characteristics of each child in the study.

Data Collection Procedures

The data sources collected during this phenomenological study included participant observations, video and audio recordings, field notes and photographs. The combination of the sources assisted in the evolution of the themes which were revealed in the data. This triangulation of data established the integrity and credibility of the findings in the study (Patton, 2002). The researcher, as a participant observer, was able to identify the subtleties and dynamics in the classroom observed. For example, the children's relationships with each other impacted the way in which they would communicate and the purposes. Two children had a strained relationship and rarely agreed on anything in the play. The video and audio recordings captured the verbal and non-verbal exchanges that occurred between the children, revealing each sought to maintain a role of power in the play, dictating what can and cannot occur. The field notes revealed the dynamics of the children's relationship such as each one sought to monopolize the toys, and would become interested after the other mentioned the toy. Triangulating the data from these sources predicated a clear and concise understanding of the math talk that occurred between the children and how it was used. The triangulation of these different data sources establishes credibility or confidence in the findings (Lincoln & Guba, 1985).

Participant Observation

The researcher was a participant observer throughout the study, as an established rapport existed between her and the children. The relationship with the children evolved to a more personal level as the children began to see the researcher as a play partner rather than another adult in the classroom. The children approached the researcher when they were comfortable to engage with her in play and dialogue (Hatch, 2002).

To stimulate math talk, the researcher engaged children in math talk through provocations. Provocations refer to listening to children talk and provoking additional thoughts and ideas through questions, behaviors or the introduction of a new stimulus (Fraser & Gestwicki, 2002). The provocations presented were questions and comments from the researcher to prompt additional math talk of the children. The questions were both open-ended and closed, depending on the language abilities of the children. Further, the researcher incorporated the provocations as she played and interacted with the children, facilitating an organic and spontaneous dialogue. The provocations did not always lead to further math talk as it was driven by the children's interest.

Field Notes

Field notes are imperative in qualitative research and should offer details of the experiences of the participants and the insight of the researcher (Patton, 2002). After each day of observation, the researcher recorded field notes to highlight key ideas and circumstances that affected the math talk. On a few occasions the researcher was able to record field notes while in the midst of the observation. The field notes were compiled and included in the data uploaded to the *N Vivo 10* software program.

Video and Audio Recording

Transcriptions. The recordings were transcribed at the end of each observational week and included both the verbatim discourse of the children as well as notes regarding the non-verbal exchanges and interactions. The researcher became immersed in the data, which prompted additional notes regarding the observations such as her interpretations, questions and thoughts. The math talk references were also highlighted to ensure the talk would be captured during the analysis.

Analysis of the Data

Coding

First cycle coding. *A priori* codes were initially established to examine the children's math talk during the analysis. The *a priori* codes used were derived from the five mathematical strands postulated in the *Texas Pre-Kindergarten Guidelines*. During the first cycle coding, the researcher coded the math talk relevant to each strand. After analyzing the strands, the *a priori* codes were refined and renamed.

Descriptive coding was also applied during the first cycle to assist the researcher in identifying and describing the children's math talk. This coding highlighted the basic topics of discussion that prompted the children's math talk. Specific play contexts were revealed that involved math talk. A coding matrix was created to show the connections and relationships between the play contexts and the math strands (Figure 1).

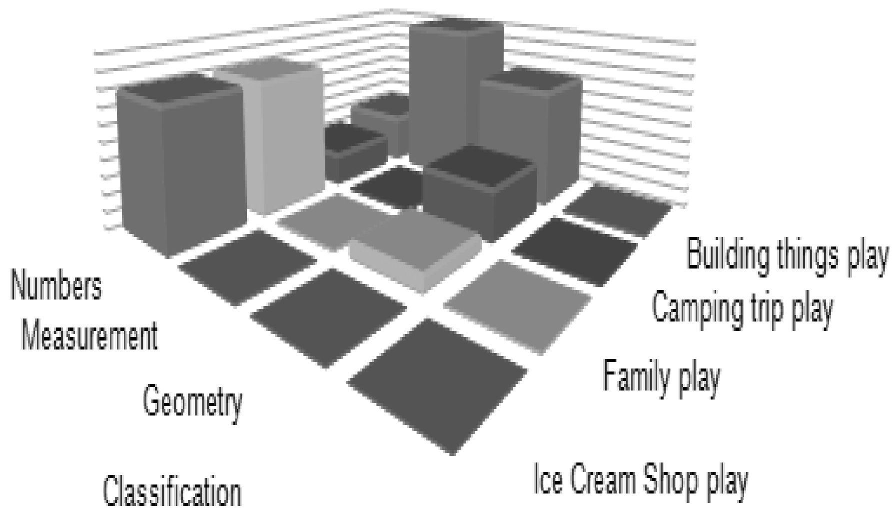

Figure 1. Coding matrix of math strands and play contexts

Second cycle coding. During the second cycle of coding, verbal exchange coding was applied, which has been described as a verbatim transcript analysis and reflection of the speaker's meanings (Saldaña, 2009). The researcher focused on the dialogic form of exchange, one of the five forms of communicative exchange described by Saldaña. This phase of coding equipped the researcher with additional information and extended to discourse analysis.

After analyzing the mathematical strands and the context of play, the researcher examined each individual child's math talk and exchanges with his or her peers and the researcher as participant observer. The researcher cross-referenced each child's talk with the first two sets of codes revealed in the first cycle of coding through a cross matrix query in *NVivo 10*. The researcher focused on the cross matrix query of each child's math talk and the mathematical strands (Figure 2), which led to discourse analysis. The alpha numeric code in the query reflected the first initial of each child's pseudonym, a gender symbol and a number.

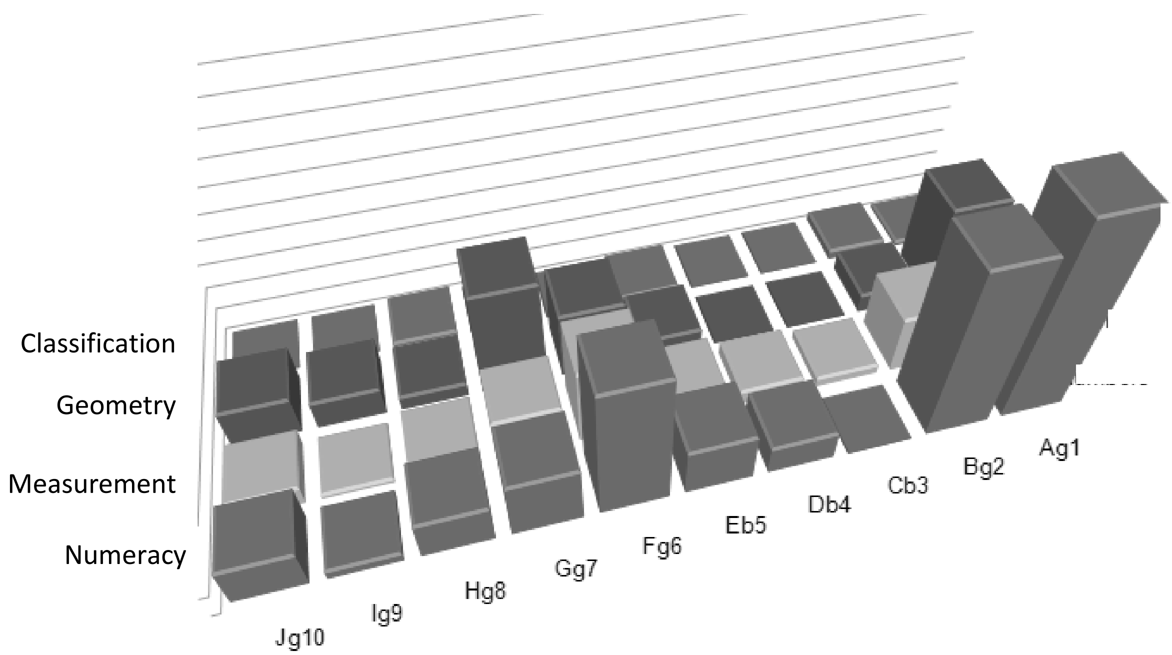

Figure 2. Coding matrix of individual children and math strands

***Discourse analysis*.** The discourse analysis guided the researcher in exploring the phenomena of math talk. Gee (2011) defined discourse analysis as a study of language as it is used, which includes the intent of the speaker. He proposed 27 tools to conduct discourse analysis. This study applied the *Doing Not Just Saying* tool, which Gee defined as the goal of the speaker; what he or she is trying to do, not just say, and understanding the goal may involve multiple purposes (Gee, 2011).

The researcher coded each child's math talk to understand the purposes of the math talk. Both the active and passive voice was noted in each of the children's math talk. Further examination highlighted the phenomena occurring in the children's verbal exchanges using math talk; what the children were trying to accomplish with the language. The researcher began to list the specific purposes of each child's math talk in the role order matrix chart. Upon reviewing the purposes and characteristics of the math talk, the commonalities of intention behind the children's math talk began to emerge. For example, in some of the math talk children were attempting to gain access to materials from another child. This was communicated not only through the word choice but also in the tone of voice, which was passive in most of these exchanges. In applying the *Doing Not Just Saying* tool the communicative characteristics and the intent of the children's math talk became apparent, uncovering the themes.

Analytic Memos

The researcher jotted memos about various ideas and thoughts throughout the analysis process as data was coded. Reviewing the memos often prompted additional thoughts, ideas and questions as the researcher would return to the original data sources. For example, after the first cycle coding the researcher wrote a memo to examine each individual child's talk and, after isolating the individual talk, return to the full transcripts to locate the conversation to gain context of the math talk. This was noted upon recognizing the individual statements of math talk did not allude to the purposes for math talk. Some of the memos began as slips of paper and were later recorded in *NVivo 10* to ensure all were captured. The research questions and the theoretical framework assisted the researcher in remaining focused on how the codes and themes connected the data.

Presentation of Themes

Research Question One (RQ1): How Do Preschool Children Use Math Talk?

Young children use speech and action to accomplish a specific task, a process deemed as one of the most important paths to cognitive development (Vygotsky, 1978). The children's math talk revealed a definite intention when spoken to others. The themes found in research question one were 1) reinforcement of rules, 2) directing and protecting play, 3) managing and accessing materials, 4) making comparisons, 5) descriptions and requests, and 6) declarations (Figure 3).

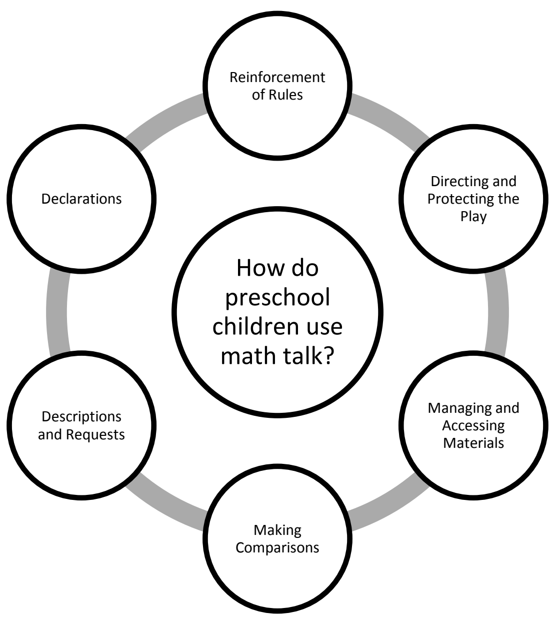

Figure 3. Research question one (RQ1) themes

RQ1-Theme 1: Reinforcement of classroom rules. The established classroom rules and routines were monitored by the teachers as well as the children during their free play. Reinforcement of classroom rules emerged as a theme in the children's use of math talk as the children reminded each other of the classroom expectations. Numeracy concepts were most common as children would discuss how many children could be in the centers at once. Though the teacher had a sign with dots representing the number of children allowed, the sign was not used as it had been in previous months since several younger children had joined the classroom. For the children who had been in the classroom when the signs were used, the sign was referenced to reinforce the rule, as exhibited in the excerpt below. The children's pseudonyms were used in the following excerpts and the researcher was represented with the letter R.

Amya: *Hey, what are you doing? There's a lot of people in here. There's too much people.*
R: *How many people can be here?*
Amya: *But there's too much people!*
R: *Well how many people do you think should be here?*
Amya: *3* (glanced at center sign with Velcro dots for names)
R: *3?*
Amya: *No, 2. 1, 2* (looked at center sign again, but this time counted the Velcro dots)
R: *2? How do you know it's two?*
Jean: *It's me in here.*
R: *So now is it 2 people in here right now?*
Amya: *Just 2!*
R: *How many are in here right now?*
Amya: *5*
R: *5?*
Amya: *There's supposed to be 2!*
Eric: *But I, I don't have nowhere to sit. I got standing up.*
Amya: *There's just 2, there's just supposed to be 2.*

Amya's dogmatic repetition of the rule, typical of a three-year old (Koymen et al., 2014), continued until the teacher overheard her and assisted in redirecting children to the other centers.

During the camping play theme, the children were playing as if they were in a boat, which was tape on the rug outlining the shape of a boat. The children had pretend oars and fish to act out the camping experience. The teacher had set the limit to two children in the boat at once. In the excerpt below, the children in the boat reinforced the rule of how many children could be in the boat.

> Jean: *I want go in boat.*
> R: *I think only 2 people can be in the boat.*
> David: *Yeah, 2. Only 2 3 yeah, 2.* (holds up his hand)
> R: *Just how many? 2*
> David: *Bianca and me.*
> R: *Just Bianca and you?*
> Bianca: *2. Bianca and David*. (touches herself and David)

Bianca and David were not going to allow Jean to enter the boat, which she adhered and later asked if they were done. Eventually, Bianca replied yes and handed Jean the oar and stood up from the chair.

Some of the children, generally younger and or fairly new to the classroom, would recall a number, though it may not have been accurate, to reinforce the rules. In the excerpt below, David, a three-year old, reinforced the rule regarding the number of children allowed in the sand table to Hannah.

> Hannah: *Hey, I wanna play with it.*
> R: *I don't know how many people can be over here. Can there be 1 person or 2 people?*

David: *1 person.* (holds up 1 finger)

A few minutes after this exchange, Hannah reinforced the rule but had forgotten which actual number word, 1 or 2, but that did not stop her.

Fiona: (goes to sand table) *It's a pancake Hannah.*
Hannah: *Only 2 people!* (Teacher redirects Fiona)

In addition to numeracy, the children employed classification as they reinforced the rules when they were told to clean up materials in the classroom. For example, Hannah noticed someone had placed a toy in the wrong container. Though it was not spoken directly to anyone and may have been more self-talk, she stated, "Hey! This don't belong here."

RQ1-Theme 2: Directing and protecting the play. The children utilized math talk to direct and protect the play they were engaged in during their free play. This was evident as children created play themes and ideas that were of interest to them and often were not willing to make any changes. This entailed role assignments in the children's play scenarios as well as permission for other children to enter into the play scenario. The mathematical concepts relevant in this theme were numeracy, measurement and geometry. Directing and protecting the play was more common among the children that were more proficient in their language abilities. Children with less language were more likely involved in parallel play until they observed something that gained their interest.

In the excerpt below, Ivy, one of the younger and less talkative children, observed Eric in the sand table. She walked over to the table and he immediately rebuffed her attempts to join him, though the teacher had said two children could be in the center.

Ivy: (comes over and picks up the boat out of sand)
Eric: *No!*
R: *Oh, Ivy he's burying the boat.*
Eric: *Don't take it out! Get away from me!* (Teacher reminds him she can be there) *I don't want 2 friends. She will wreck it again!*

In the following excerpt, Amya had decided to pretend they were going camping in the car. She had taken on the role of baby and laid across the two chairs in the center. Bianca wished to sit in a chair and, in response to Amya's directions, went to get another chair from the table, placing it in front of Amya. The teacher, a substitute for the day, reminded the girls only two chairs should be in the center.

Amya: *But someone has to sit in the front.*
R: *But Ms L says only 2 chairs can be back here.*
Bianca: *No.*
R: *Can you put one back Bianca?*
Bianca: *No!*
R: *Who's going to put the chair back?* (No response)
Bianca: (Attempts to sit beside Amya)
Amya: *That's where my feet go. Someone has to sit in the front and drive me!*
Bianca: (Returns to chair in front)

Amya, using spatial words, insisted someone must sit in the front seat. She directed the play scenario and was not open for compromise, despite the teacher's reminder. Bianca unsuccessfully tried to sit beside Amya, which led to her decision that the chair was necessary since Amya had directed her to sit in the front.

The following excerpt illustrates how Bianca protected the camping play with Cary, as Amya tried to enter the tent, while calling for Cary, a child with limited English, to get out. Bianca refused to adhere to Amya's argument and protected Cary's right to be in the tent with her.

Amya: *I wanna sleep!*
Bianca: *No you can't. It's 2 bodies in here.* (She and Cary)
R: *How many people can be inside of the tent?*
Bianca: *1 2.* (Touches herself and Cary)
Amya: *I want to be in here!*
R: *Did Ms. R say who could be in it? Did she say a number or no?*
Amya: *She did.*
Bianca: *No, 1 2!*
Amya: *No, I was in here.*
Bianca: *No, 1 2!*
R: *Did she say how many?*
Amya: *She said 2.*
Bianca: *1, 2.*
Amya: *I was going in there.* (Walks away)

Amya's approach had worked at times but Bianca was adamantly protecting the play she and Cary began before Amya's arrival in the center.

RQ1-Theme 3: Managing and accessing materials. The children were attentive to the resources and materials available during their play and used math talk to determine if there were enough materials to distribute to others. Children seeking more materials would make statements about what they wanted or needed to join or continue their play. Within the math talk, the children exhibited all four of the mathematical concepts: numeracy, measurement, geometry and classification.

The children that were managing materials were immediately in a place of power and those who wanted access were expected to either accept or refute the offerings of the manager to gain materials. This occurred among all the children at some point over the observational time. A few of the children regularly refuted another child who was managing materials. This approach was not necessarily successful all the time but had been on occasion.

Gabby: *I want more I want more I want more!*
Amya: *Can I have one, can I have one?*
Fiona: *We don't got no more.*
R: *You don't have anymore?*
Fiona: *No!* (To Amya) *No don't get a lot*. (To Gabby)

Gabby was successful in demanding more puzzle pegs from Fiona but Amya was not, though there was an abundance of pegs available.

As a participant in much of the play, the researcher found herself in the middle of these exchanges, sometimes being drawn in to assist with accessing materials. The language abilities of the children also played a role in their success in accessing materials. The children with more language were specific in negotiating to gain access to materials.

Amya: *I just have 3.*
R: *How many do you have in your bowl?*
Amya: *Just 1 2 3 4.* (Counting)
R: *So you have 4 scoops of ice cream; that's a lot of ice cream.*
Amya: *1 2 3 4.*
R: *How many do you want?*
Amya: *5.*
R: *You want 5. Fiona can you give her a scoop of ice cream?*
Amya: *I want to make my own!* (Begins scooping out of Fiona's carton)
Fiona: *Waaaaaa!* (Amya takes several balls)
R: *Ok, she got 1 scoop and now she's done.*
Amya: *I didn't get 5.* (Took about 4, much more than expected)

Though the researcher asked Fiona to give Amya a scoop, Amya took the scoops she wanted, ignoring Fiona's whine. Amya also had more language and exhibited greater mathematical knowledge than the other children, which she often used to her advantage.

RQ1-Theme 4: Making comparisons. Math talk was also employed to facilitate discussions that involved making comparisons among objects, people and abilities. In this theme, children used numeracy, geometry and measurement concepts to make comparisons. The children often determined the item they would build or evaluate their work by comparing to another.

The ability to make comparisons regarding size has been noted in toddlers as young as two and a half years old (Reikerås, Løge, & Knivsberg, 2012). Based on Piaget's (1970) explanation of knowledge construction, the children exhibited physical knowledge as they observed and discovered the properties of objects as well as logico-mathematical knowledge when they manipulated objects and determined relationships between objects. In the excerpt below, Bianca shares her physical knowledge about sizes.

> Bianca: *You big; I'm big too.*
> R: *You're big and I'm big too? Am I bigger than you?*
> Bianca: *Yeah. You little and I big.*
> R: *I'm little and you're big?*
> Bianca: *No, you bigger and I little.*
> R: *Yes, I'm big and you're little.*
> Bianca: *Yeah. You little and I big.*
> R: *I'm little? I guess I can be small.* (R sits in small chair)
> Bianca: *No!*

Bianca knows the researcher is bigger than she but also knows she is considered to be big amidst her peers, as she was slightly more solid than some of the other children. As the exchange continued, she seemed to get the words confused but continued with the comparisons.

The exchange below involved the children building in the construction center and making comparisons between the two builds. As they were manipulating the blocks, Amya exhibited logico-mathematical knowledge in making comparisons.

> R: *What are you guys going to build?*
> Jean: *Umm building a castle.*
> Amya: *A castle, just like Rapunzel has.*
> R: *So is it a big castle?*
> Amya: *Yes*
> Jean: *Big castle.*
> Amya: *It's going to be a tall castle.*
> Jean: *Tadaa!*
> R: *Wow, I see it.*
> Amya: *It's not tall, it's just short. You build one like I have.*

RQ1-Theme 5: Descriptions and requests. The math talk was evident as children described things and people as well as made requests in their play. The descriptions and requests involved three of the mathematical concepts, excluding classification, while numeracy and geometry were most prevalent. The children were specific in describing how things moved through a space as well as the quantity of objects. The children making requests used math talk to explain what they wanted to accomplish. The excerpt below shows Ivy using spatial words to describe what she wants to do with her puppy.

> Ivy: *I want put my puppy in.*
> David: *I help you guys.*
> R: *You'll help us?*
> Ivy: *I want put my puppy in.*
> R: *She's trying to build something to put her puppy in. She needs a kennel. You're going to build it for her?*
> David: *Yeah.*
> Ivy: *I need my put my puppy in?*

Ivy repeatedly communicates she wants her puppy in one of the structures built. Initially, she wanted to put it inside of a structure David built but he would not agree, and stated the structure was for his snake. Ivy continued with the use of spatial words as she described where she had the puppy moving around the blocks in the construction center.

> Ivy: *He swimmed over.*
> R: *He swims over?*
> Ivy: *He turns down. He jumped down, he jumped over.*

Children also used math talk to describe the quantity of objects or to make requests of what they needed. In the following excerpt the children described the experience that occurred in the pictures drawn using quantity.

> Amya: *I had 5; 4 balloons.*
> R: *You had 4 balloons?*
> Fiona: *No, it just 1.*
> Amya: *No, I had 4 balloons!*
> R: *You had 4. How many did you have Fiona?*
> Fiona: *I had 1 balloon.*
> R: *Okay.*
> Amya: *And then 1 pops and I got another another another.*
> R: *Did they all pop?*
> Amya: *Yeah.*
> R: *So how many balloons do you have now?*
> Amya: *None.*

RQ1-Theme 6: declarations. The children would often make matter of fact comments about something which involved math talk. For the children, the comment was fact-based and was stated as such. Numeracy and geometry were the primary mathematical concepts referenced in the children's declarations. The declarations were comments about the child's life, such as his or her age, a comment regarding an observation or a corrective statement in response to something someone else may have said.

Fiona: *Yeah. I need birthday candles.*
R: *You need some candles?*
Fiona: *Yeah.*
R: *Well where are the candles? Are there candles anywhere?*
Fiona: *1 2 3 4 6, that's what I have.*
R: *Oh, okay.*

Fiona, though incorrect, counted and then concluded that's what she had. Jean had recently returned from an extracurricular activity and shared the number of stamps received.

Jean: *I got 2 stamps cause I was being good today*.
R: *What, they gave you 2 stamps!*
Jean: *Because I, I be good today*.

The preschool children in this study used math talk to accomplish various goals in their play. As Gee (2011) suggested, the children used their math talk to not only state their ideas but also to do something, such as reinforcing the rules, directing and protecting the play or making comparisons. Also, children with advanced language skills were more savvy in applying math talk for different intentions.

Research Question Two (RQ2): How do Preschool Children Communicate Changes in Their Mathematical Thinking?

Mathematical thinking develops as a process to understand and communicate, both internally with oneself and externally with others (van Oers, 2010). When presented with evidence contrary to an initial thought, young children make a shift in their thinking (Copley, 2000). Piaget (1950) regarded this accommodation of thinking as the way in which children resolve the mental conflict. After an in depth analysis of the children's math talk, the process of communicating the shift in thinking was uncovered. The themes were 1) sharing and applying knowledge and 2) restating ideas (Figure 4).

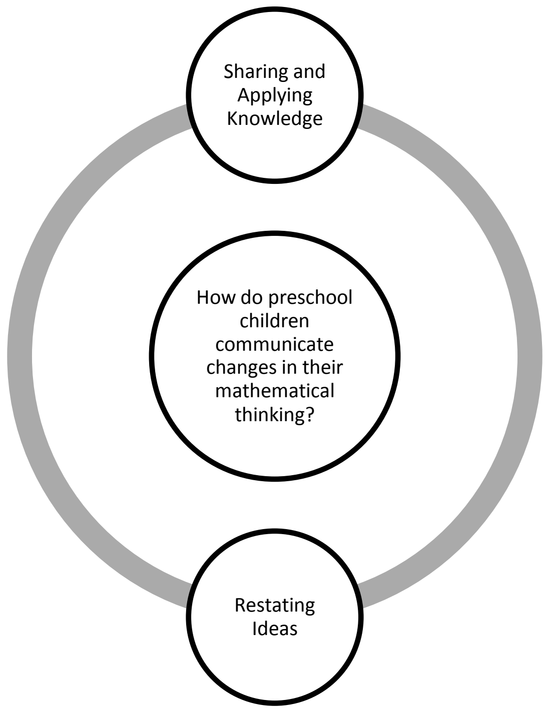

Figure 4. Research question two (RQ2) themes

RQ2-Theme 1: Sharing and applying knowledge. To communicate the changes in their mathematical thinking, the children would share or apply new knowledge with others. This process was evident as Jean asked for the researcher's help to complete a floor puzzle with over 12 large pieces. In the beginning, she asked her to assist with the puzzle. In doing so, the researcher talked to her about the pictures she saw on each piece, such as the monkeys, butterflies and birds.

R: *Hmm, what other animals do we have to find? What is this little animal?*

Jean: *Monkeys.*
R: *Those are monkeys.*
Jean: *Yes.*
R: *We've got to find the other one, because there's one right here but his face is missing.*
Jean: *Whoa, whoa whoa! Wow, I remember this one!*

Shortly after Jean completed the puzzle Amya wanted to do the puzzle with Jean. The excerpt below shows Jean sharing her newly acquired spatial awareness knowledge with Amya about the puzzle.

Jean: *Right here.*
Amya: *I want to do another puzzle.*
Jean: *Hold on, I'm trying to do this one.*
Amya: *How does it go?*
Jean: *I, I did it!*
Amya: *Are you, can I do the last piece?*
Jean: *Not yet.* (Completes puzzle and reviews pictures of animals) *Now you turn.*
Amya: *Can you, I want to do it by myself. How am I going to do the puzzle?*
R: *You have to take it apart.*
Amya: *You want to take it apart? Where does this go?*
Jean: *It goes.* (Points to correct place)

Jean's initial experience with the puzzle was her time to research and experiment with the puzzle after which it became her personal knowledge, which she wanted to share with Amya.

The children interpreted and applied new vocabulary surrounding the math talk, such as the names of shapes or terms regarding capacity. As Gabby played with a shapes puzzle, the researcher referred to one shape as an octagon, one she had simply called shape earlier. After the exchange, Gabby incorporated the word in her explanation of the shape, proclaiming she needed an octagon. In the excerpt below, Hannah, a child who had spoken only on occasion, acquired the word and understanding of “fit” after hearing the researcher and another child discussing whether a bracelet would fit.

R: *You put them on; they don't fit on my hand.*
Gabby: *Look it fits.* (Puts bracelet on her wrist)
Hannah: *Let me see. Put it down.* (Reaching for my hand)
R: *Put it down? You want to see if it fits? It doesn't fit, my wrist is too big.*
Hannah: *It fits me.*
R: *It does. Your wrist is smaller than my wrist. See how big mine is and how little yours is.*

RQ2-Theme 2: Restate the idea. The children also communicated changes in their mathematical thinking by restating the idea they initially had. Sometimes the change was prompted by a question that apparently caused the child to rethink the idea. This was noted as Amya was reinforcing the rules but restated the number of children allowed in the center.

R: *Well how many people do you think should be here?*
Amya: *3.*
R: *3?*
Amya: *No, 2. 1, 2.*

The children made changes regarding initial observations and communicated the change by restating the idea in their play with the researcher as well as their peers. In these situations there was not a question but the child re-examined the subject of the observation.

Bianca: *Alligator.*
R: *You found an alligator.*
Bianca: *2 alligators.*
Jean: *2 alligators.*
Bianca: *Not 2 alligators!*
R: *Not 2 alligators, are they different?*
Bianca: *Yeah!*

Bianca realized it was not really two alligators after Jean repeated what she had stated. Bianca restated her observation upon closer examination of the two animals and recognized they were different.

The children communicated the changes in their mathematical thinking by sharing knowledge and or restating ideas. The children did so when provoked by knowledge acquired in a previous interaction or observation. This was also evident as children made statements and then changed their initial statement after re-examining the information before them.

Summary

This chapter presented the description of the participants in the study, the data collection procedures, the analysis of the data and the themes revealed in the data. Piaget's theory of cognitive development was the lens used to understand the children's mathematical thinking and development. Vygotsky's social cognition theory was applied to examine the children's cognitive and communicative processes as they engaged in math talk. During the analysis of the data two cycles of coding were applied to the data to uncover the themes. The themes were introduced to explain the phenomena of preschool children's math talk and the process they went through to communicate changes in their mathematical thinking.

CHAPTER V

DISCUSSIONS, FINDINGS AND IMPLICATIONS

Introduction

The purpose of this phenomenological research study was to explore young children's use of math talk. The children's math talk was examined with a theoretical lens guided by Jean Piaget's theory of cognitive development and Lev Vygotsky's social cognition theory. Piaget's theory was applied in understanding the children's mathematical thinking and logico-mathematical knowledge, while Vygotsky's theory informed the verbal exchange among the children as they were engaged in math talk. Two research questions were analyzed in this study.

1. How do preschool children use math talk in their free play?
2. How do preschool children communicate changes in their mathematical thinking?

The researcher's observations, field notes, audio and video recordings and analytic memos were collected to inform the study. This chapter presents a summary of the study, discussion of the themes, implications for early education professionals and parents of young children and recommendations for future research. The study conclusions and limitations are also discussed.

Summary of the Study

This qualitative research study employed a phenomenological approach to examine children's math talk in a preschool setting. The exploration of math talk was chosen as the focus of the research due to the dearth of studies focused on mathematical thinking and communication of young children. Much of the mathematical research that has been conducted with young children has focused on mathematical manipulations and the informal mathematical knowledge they have as a foundation of mathematical concept development (Anthony & Walshaw, 2009). This research study examined both the mathematical thinking and communication of young children, resulting in math talk.

Phenomenology was a fitting approach to this study because this type of research is designed to describe and interpret the lived experiences of the participants (van Manen, 1990). Welsh (2013) suggested the application of phenomenology is imperative to capture the experiences of children, since the adult can no longer access childhood experiences without the interference of the totality of his or her lifespan experiences. Therefore, phenomenology was necessary to interpret and understand the phenomena of young children's math talk.

The construction of children's mathematical knowledge is a personal cognitive process young children experience as they interact with people and objects in their environment. Two of the three types of knowledge Piaget (1970) suggested were focused on in this study: physical knowledge and logico-mathematical knowledge. Physical knowledge, as described by Piaget (1970), is constructed during the child's observation and exploration of properties of objects, while logico-mathematical knowledge develops as children manipulate objects and discover relationships between actions and objects.

Construction of mathematical knowledge is inherent on the thinking that occurs within young children and is only made visible through their language (Vygotsky, 1962). Moving from thoughts to words, children become capable of expressing their thinking. The dialogue that ensues, a back and forth exchange of language, promotes deeper levels of understanding. It was the restricted amount of research on the connection between mathematical thinking and language that was the impetus of this study.

The population participating in the research study was a convenient sample, since the researcher was professionally connected to the child development center. Ten children in the two and a half to three year-old classroom were the participants in the study. This classroom was chosen because the children had not yet received formal mathematics instruction, which allowed the researcher to focus on the children's math talk as they constructed mathematical thinking based on their activities and interactions.

The leadership of the child development center was contacted by the researcher to obtain the appropriate permission to conduct the study. Upon their approval, the researcher invited parents to an informational meeting to explain the research and procure consent for the children's participation in the study. All the parents were forthcoming with the consent forms and agreed to allow the researcher to record the children's daily classroom interactions.

The data collected throughout the study included the researcher's participant observations, field notes, audio and video recordings, and photographs of the classroom setting. The collection of data sources resulted in a triangulation of the data that strengthened the study (Patton, 2002). Analysis of the data included analytic memos, coding, discourse analysis and a thick description of the children's experiences and math talk in the classroom. This triangulation during the analysis process resulted in eight themes: 1) reinforcement of classroom rules, 2) directing and protecting the play, 3) management and access of materials, 4) descriptions and requests, 5) making comparisons, 6) declarations, 7) sharing and applying knowledge, and 8) restating ideas.

Discussion of Themes

The data collected was analyzed through a first and second cycle of coding. The coding guided the researcher in identifying the eight themes evident in the data. The first research question about children's use of math talk yielded six themes: 1) reinforcement of classroom rules, 2) directing and protecting the play, 3) managing and accessing materials, 4) descriptions and requests, 5) making comparisons, and 6) declarations. The second research question regarding the communication of changes in mathematical thinking yielded two themes: 1) sharing and applying knowledge and 2) restating ideas.

Research Question One (RQ1): How Do Preschool Children Use Math Talk?

The use of language does not simply entail communicating information but it also can accomplish other tasks. Gee (2011) proposed language facilitates doing and being things, achieving a myriad of goals through language. The analysis of the children's math talk uncovered specific goals of their talk and pointed to six themes.

RQ1-Theme 1: Reinforcement of classroom rules. The first theme identified in the data was the reinforcement of classroom rules. When two and three year-old children are faced with another child not following the established rules, they often intervene and protest against the rule breaking (Koymen et al., 2014). Whether created by an adult or the children, young children expect the rules to be adhered to consistently. In this occurrence the children would take on a slightly different role or being in the speech to communicate a classroom expectation or rule (Gee, 2011). Numeracy concepts were the primary math concept involved in reinforcing rules. This was noticed as the children played throughout the classroom especially in camping trip play.

In the classroom, the social norms were based on the rules, routines and procedures the teacher had established. Young children follow and often reinforce the social norms adults or older children create. The children have internalized the social behavior and language that was previously external, communicated by someone else, a process Vygotsky referred to as internalization (1978). With the internalization and understanding of the rule, the children were capable of recognizing a violation of the rule. This has been noted in three year-old children and, to some degree, two year-olds (Schmidt & Tomasello, 2012).

Children who had been in the classroom for several months often reinforced the rules with other children newer to the classroom. The teacher had initially established specific rules regarding the number of children allowed to play in the centers. For example, the dramatic play center was limited to three children, but some days the children would covertly exceed the number by one or two. If another child noticed, he or she would reprimand the child and reinforce the rule. This often occurred when the center had new, exciting materials such as the tent displayed for camping in the dramatic play center.

If the teacher revised the number allowed in a center, which was common in the sand and water table, she would simply state the new number in the morning. In those situations, usually the child playing in the table would take it upon him or herself to reinforce the rule. The social knowledge was communicated by the teacher and was added to the child's memory (Piaget, 1970).

The younger or less verbal children that engaged in reinforcing the rules would simply mimic the teacher's comments regarding the numbers allowed in the centers, though not always accurate. The children's tone and physical responses were slightly aggressive when reinforcing the rules, with finger pointing and raised voices. This behavior may indicate the children's perception of the teacher's body language when telling the children the classroom rules.

As Koymen et al. (2014) suggested, children are capable of enforcing the norms that are taught at a very young age. The children's use of math talk to reinforce classroom rules was additional evidence of this ability. The children accepted the rules and reinforced them, especially when adherence to the rules was to their benefit.

RQ1-Theme 2: Directing and protecting the play. The second theme uncovered in the data was directing and protecting the play. The children often engaged in math talk when involved in play they had created and or wished to maintain. The children would develop their play and were not often open to making compromises or changes to the play. The children used the math talk to direct and protect their play. This math talk involved multiple mathematical concepts, including spatial awareness, numeracy and measurement. It was evident in all four of the key play context: camping trip, family play, building things and ice cream shop play.

Directing and protecting the play involved positional words such as where a child was permitted to sit in a play scenario. One child directed another child to get under the table because the child directing the play wanted to place her feet in a chair, preventing the other child from sitting in the chair. The number of roles that were allowed in the play was also a common way in which the play was directed, such as insisting only one baby and two big sisters were allowed in the family play.

The use of math talk when directing and protecting the play was more common among the children with more language. The more sophisticated the children's math talk, the more likely they were able to direct the play of others. Their language abilities allowed them to employ their logico-mathematical knowledge to not simply manipulate objects but also others (Piaget, 1970). The children were able to articulate the play scenario, telling the other children their task or role in order to join the play. This involved all the play contexts such as building things when a child directed another to build a tower that was a specific size and included only certain types of blocks.

Because math occurs in social situations in classrooms, it is not uncommon for children to direct their peers in play (Edens & Potter, 2013). This process was not always successful, especially when the most verbal children attempted to direct and protect the play with each other, prompting disagreements. In one case, the two most verbal children had a disagreement as to who could play in the tent. The child that arrived to the center after the play had begun insisted the less verbal child depart from the tent so she could enter. Her advances were suppressed as the initial child protected the less verbal child's right to be in the tent. The play that had been established was not changing based on the demands of the other child.

Directing and protecting the play of the children was evident in all the observed play contexts and incorporated multiple mathematical concepts. The children were often adamant about the play they created and were not always open to compromises proposed by their peers. This purpose was most common among the children that exhibited advanced language abilities. As Vygotsky (1978) proposed, the children's language allowed them to impact the behavior of others.

RQ1-Theme 3: Managing and accessing materials. The third theme that was noted in the data was the management and access of materials. The children used math talk to determine if there were enough materials to share with others and to obtain materials in the play. Numeracy and geometry were the most common mathematical concepts. The play context included building things, ice cream shop play, and family play.

Children between two and three-years old accept visual cues of ownership, not disputing with the child that had accessed the toys first (Blake, Ganea & Harris, 2013). As children get older the verbal claim of ownership becomes more robust than the visual cue. This was evident as children would obtain the object, take ownership, and manage the toys. For example, the child arriving in the center first would often choose a basket of manipulatives such as Lego blocks. As other children would seek access to the toys, the first child would manage the blocks and distribute as desired. This was determined with specific details such as the shape of the block each child could have. At the light table, which included a container of shapes, the children would often assign only one shape per child. The child would attempt to build something with the singular shape and, if need be, would request another shape from the manager, who would then decide if this would be allowed or not. On occasion, the manager was overthrown by another child.

When engaged in family play this would often occur since there were limited numbers of items like baby dolls, blankets and bottles. The manager of the toys would decide if there were enough materials, such as blankets, for each child who wished to hold a baby. If the children were pretending to be the babies they were given the necessary materials.

Gaining access to additional toys was also common in these situations and determined if the child could join in a type of play. In one situation, two girls had been building stacks of pegs when another child approached asking for pegs to build with them. The child managing materials determined there was not enough for the third child to join their play, though there were several pegs to share. The manager of the materials was primarily concerned with the pegs that would be available in the dyadic play and was not open to a third player, a common response of young children (Paulus, Gillis, Li & Moore, 2013).

The management and access materials would also create a difference in the power of the children, a desirable asset in preschool children's play (Evaldsson & Tellgren, 2009). The child managing the materials was in a position of power and control, putting the child attempting to access materials in a position of submission or exclusion. The outcomes varied dependent on the amount of resources and the relationships among the children on that day, as this also varied for many of the children.

The prosocial relationship among the children was also a factor in the management and access of materials. Two of the children often seemed at odds in the play and were not as social with each other, to the point where the teacher would subtly separate them by asking one to join her in another activity when they ended up in the same play area. If one of the two was managing materials it was less likely the other child would gain access to materials. The phenomena aligned with the findings of Paulus and Moore (2014) which suggested a decrease in sharing between non-social peers.

Managing and accessing materials was one of the goals of the children's math talk. The children managing the play would determine if there were enough materials to distribute and, if so, how many children they were willing to share the materials with. Gaining access of materials put the children in a position of submission, which was not as comfortable for some of the children. Further, the children's social dynamics also played a role in making the decision to allow access to the materials.

RQ1-Theme 4: Making comparisons. Making comparisons was the fourth theme discovered in the data. Young children begin to make comparisons between objects and people prior to the age of three years-old (Reikerås, Løge, & Knivsberg, 2012). This was evident as the children engaged in comparisons throughout their play. The children overwhelmingly applied measurement concepts in making comparisons. It was more common when children engaged in the building things play context.

The children often made comparisons between the sizes of objects they were playing with. When building things, the children would discuss the structures using comparative words, such as more and bigger to compare two objects. Sometimes the comparative words were used though there was only one object they were referring to. For example, a child said he was making a bigger structure but there was nothing visible that he was comparing the new structure to. In these cases the children may have been referring to a previous build that remained in their visual memory. Interestingly, the children refrained from any superlative words such as biggest or smallest, suggesting the concept of verbally comparing more than two objects had not developed.

The size comparisons were also common as children discussed their height, stating they were taller or bigger than an object and each other. Children made accurate statements about their height, showing some body self-awareness, which becomes evident in children around two and a half-years old (Dunphy-Lelii, Houley, McGivern, Skouteris, & Cox, 2014). The teacher had a large flower used as a pointer and the children each excitedly stood next to the flower to point out they were taller than the flower. This was also common as children were building large structures, standing next to a tower to point out they were taller than the structure.

The math talk also involved comparisons to the size of the researcher compared to the teachers in the classroom. Further, during the children's play the researcher was invited to put on different items like chain bracelets or headbands. When the researcher explained it would not fit her, the children often responded with comments such as "you too big?" making a comparison between her stature and theirs. This was more common among the younger children as their reasoning about object characteristics lags behind their body self-awareness (Brownell, Zerwas, & Ramani, 2007).

A couple of the children made comparisons regarding the weight of objects on a few occasions. When building with blocks a child suggested one block was too heavy for the tower, though it was actually a cardboard block that was visibly larger than all the wooden blocks. Another child was using the blocks to build a structure and, when she lifted the longest wooden block she said it was a heavy one and acted as though it was a struggle to move. Again, this comparison was with a previously manipulated lighter block though not referenced in the comment.

The quantity of objects was also described as children used math talk to make comparisons applying quantitative words such as more or a lot. These approximations were made by looking at a group of objects and determining if they had "a lot" or just a little, which often occurred when justifying the need to gather additional objects like blocks. Their use of quantitative words hinged on their definition of the words, unique to each child. For example, one child argued she only had a "little" ice cream balls while another child with the same amount in a different sized bowl, was content that she had "a lot". This discrepancy between the two was an example of Piaget's explanation of conservation wherein children did not see the difference in quantity based on the object but focused on the container the object was in (Piaget & Szeminska, 1977).

Math talk that involved making comparisons was discussed throughout the classroom and day. This incorporated making comparisons between the sizes of objects and people, common when children were engaged in building things. It was also referenced as children made quantitative comparisons as they either counted or approximated the number of items.

RQ1-Theme 5: Descriptions and requests. Making descriptions and requests was the fifth theme discerned in the data. This was evident in all mathematical concepts except classification. It was also apparent in every play context observed.

The children used math talk to give descriptions of what they were doing or making. As the children engaged in building things they often described their structure with math words to explain the size such as making something big. In one discussion a child described she was building a big spaceship and needed a specific type of block. Children would describe what the final structure would be prior to finishing the building, suggesting the children were engaged in verbal planning, an advanced intellectual activity (Vygotsky & Luria, 1993).

The descriptions and requests involved spatial words as the children described where things were in space, most common in the building things play. As the children played with toy animals and dolls in the construction center they explained how the items moved, such as up, over or down the towers. These constructing and building experiences have been identified as a necessity to facilitate children's spatial math talk (Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011). The children made references to where they had to place blocks to complete their structures with positional words such as beside, behind or under. This was also common when they described where something was placed, such as on top or on the shelf. Spatial words were also referenced when a child requested a specific toy.

Numeracy concepts were common in the children's descriptions and requests as they applied number words. A discussion about balloons involved the children describing the number of balloons they had at a party and what happened as the balloons popped, which was illustrated in a drawing. The children described what was occurring during the play when they designated roles in the play and requested specific things needed to extend the play. One example of this play was when the children were making birthday cakes with pegs and peg boards, requesting four candles for the cake.

Children employed math talk to make request for toys or materials in the classroom. This was evident throughout the play as children would seek out materials. The children would request a specific number of shapes or blocks or describe how many more pieces were needed to complete a puzzle. They often requested a number of items that were needed for them to join in the play.

The math talk employed in descriptions and requests also involved non-numerical quantitative words. When children were pretending to be babies during family play they would often request more milk. As they played in the ice cream shop they requested more ice cream or described what they had as “a lot.” The use of non-numerical words involves the Approximate Number System (ANS), which is an innate mental system that approximates the magnitude of a set of objects. ANS has been found to be a pre-cursor to formal mathematical knowledge (Mazzocco, Feigenson, & Halberda, 2011). The children were able to utilize their ANS knowledge to engage in math talk.

As children were engaged in math talk, some of them were able to subitize, which is the ability to accurately name the number of a small set of objects without counting (Gray & Reeve, 2014). Specifically, one child playing with the toy cars was able to look at two of the cars and immediately state the number of cars without counting. Subitizing has been described as a foundational skill for children’s mathematical abilities (Myoungwhon, Hartman, Smith, & Wallace, 2013). Subitizing was observed in only three children in the classroom.

Descriptions and requests were a common purpose of math talk in the classroom. The children would describe things such as the quantity, shape, and spatial position of things. Requests were often made with the use of math talk as they would seek out various toys and items necessary for their play.

RQ1-Theme 6: Declarations. The sixth theme revealed in the data was declarations of the children. The declarations of the children were noted as the children made comments and statements in their math talk to communicate age, quantity, and various things observed or experienced. Geometry and numeracy were among the primary mathematical concepts referenced. Declarations were apparent in all of the play contexts except camping trip play.

The children made declarations as they told others about their experiences in other settings. The declarations were expressed with confidence as the children seemed sure of their comments. This non-reflective, unarticulated quality of experience is often referred to as tacit knowledge (Nash & Collins, 2012). Tacit knowledge is often unconscious and routinely used but taken for granted by the user. The accuracy of the knowledge is not considered, as it is truth to the individual. One example occurred when a child that told the researcher about a birthday party she had attended for a friend that was four years-old. When asked if the friend was older than her she declared they were the same age, though the child was actually three years-old. Later, during another discussion, the child discussed three prizes she earned at home and where her mother had placed them. Another child that participated in an extra-curricular activity entered the classroom and announced she had received two stamps because she was good.

The passage of time was referenced in some of the declarations. A child stated her mother was going to let her watch television the next day, using the word tomorrow. She went on to say she watches it sometimes but not all the time, exhibiting some understanding of time. During a play theme the children stated there were only five more minutes till they had to wake up the babies.

Declarations were made as children engaged in various play in the classroom. For example, the children would pretend they were going shopping for an item and express the amount of dollars needed to purchase the items. When the children were in the ice cream shop play one child picked up the phone and pretended to take an order, turning to tell the others how much ice cream the customer wanted and the cost.

The declarations also occurred when a child gave information to another child. On a few occasions, one child would correct another child's comment. For example, two children were drawing pictures and one child said she had two balloons in her picture. The other child leaned over and said she saw five balloons in the picture, correcting the other child's count. In this situation, the child shared declarative knowledge she had acquired which was fact-based and had become an aspect of her memory of the counting process (Hayne, Boniface & Barr, 2000).

The children's use of declarations during the math talk was evident in several conversations. The children talked about their experiences outside of the classroom setting, making declarative statements regarding the home and extra-curricular activities. The declarations were also made as the children engaged in pretend play, as they stated the costs of items and sizes of structures to be built. On rare occasions, a child would make comments to correct another child's observation.

The children's use of math talk was prominent throughout the observations and served several different purposes. The children used math talk to accomplish several goals as reflected in the six themes: 1) reinforcement of classroom rules, 2) directing and protecting the play, 3) management and access of materials, 4) descriptions and requests, 5) making comparisons, and 6) declarations.

Research Question Two (RQ2): How Do Preschool Children Communicate Changes in Their Mathematical Thinking?

RQ2-Theme 1: Sharing and applying knowledge. The first theme discovered in the data in response to question two was sharing and applying knowledge. The communicated changes, though rare, were evident at various times with a small number of children. The children would take on the role of expert when their mathematical thinking evolved to another level of understanding. This was noted in children's math vocabulary and in their spatial awareness.

The children appeared eager to share the knowledge recently acquired with another child, giving them an opportunity to act as the experts. The expert role, typical of adults and older children, was one they took upon themselves. For example, a child who had just learned the process of completing a new puzzle, with the help of the researcher, became an expert when another child wanted to complete the puzzle. The expert child, using spatial awareness, pointed out the correct placement of the puzzle piece to the child. The expert was not prompted to assist the novice child but naturally assumed the role. Johnson-Pynn and Nisbet (2002) had the same findings when researching preschool children tutoring a peer. They found young children spontaneously used both verbal and non-verbal cues to facilitate the success of the novice child. Another child who had become quite adept and knowledgeable of a puzzle, having played with them frequently with the teacher, became an expert. When another child, new to the classroom, saw her skill he sought her assistance to guide him in completing the puzzle. She shared her knowledge and pointed out where each piece needed to be placed and prompting him with the picture.

Some of the application of knowledge occurred as the children learned new math vocabulary terms. This occurred as a child was telling the children she needed a shape, pointing to an octagon. The researcher, noticing the reference, named the shape. Shortly thereafter the child was telling others she needed an octagon. She had immediately applied the new vocabulary word to her description of the shape needed. As Vygotsky described, the child had learned the term through interactions with a more knowledgeable person, the researcher, and was able to deepen her knowledge of shape names (Vygotsky, 1978). Another child with minimal expressive language in the beginning of the research study began to talk to the researcher using math talk. She discussed numeracy concepts and capacity as she listened and engaged with both her peers and the researcher. Interacting with a responsive adult enhanced her math talk, as suggested by Cabell et al. (2011). In their examination of vocabulary acquisition they found teachers and parents that initiated responsive strategies such as reciprocal interactions prompted greater language productivity in children.

Sharing and applying knowledge was evident as the children interacted with their peers. In the puzzle play, the child sharing the knowledge took on the role of expert. This was noted during puzzle play as the expert child shared recently acquired spatial awareness knowledge regarding the puzzle. The children also applied knowledge gained as they incorporated the math words into their vocabulary. The names of shapes and terms describing capacity were noted additions to some of the children's math talk.

RQ2-Theme 2: Restating ideas. Restating an initial idea was the second theme uncovered in response to question two. The children, when making a change in their mathematical thinking, would restate an earlier comment about an observation. This was noted in only two of the children's math talk, both of whom were quite verbal compared to most of their peers in the class. They were able to use the tool of language at a more advanced stage than the other children.

The children restated ideas during interactions with a peer. One example occurred when a child initially said two items were the same. Another child repeated what she had initially said, at which the child restated her idea and said the items were not the same. Listening to the child repeat the items seemed to prompt her to rethink what she said and make the change. She revised her physical knowledge initially communicated regarding the characteristics of the toys once it was verbalized by another child (Piaget, 1970).

The other child that was noted restating ideas did so in her math talk with the researcher. Initially, she told the researcher she had a triangle. She looked down at the shape after saying the shape and corrected herself by saying it was a square. She seemed to know the shapes but needed another moment to notice the attributes of the shape.

Evidence of the children communicating changes in their mathematical thinking was not as prevalent in the math talk. A limited number of children revealed changes in their mathematical thinking through the math talk. The few children that were communicating changes through their talk revealed two themes: 1) sharing and applying knowledge and 2) restating ideas.

Implications

The purpose of this study was to examine how preschool children used math talk in their free play and how they communicated changes in their mathematical thinking. The findings in this study suggest much can be learned from the phenomena of young children's math talk. Math talk serves many purposes for young children, as revealed in the data. It exhibits their mathematical thinking and construction of new thinking. The study findings have implications for both early education professionals and parents that can contribute to and expand the mathematical experiences, thinking and communication of young children.

Early Education Professionals

Early education professionals that develop instructional content and teach young children should deepen their understanding of children's math talk. Closely examining children's math talk in their play can give guidance on strategies to appropriately extend their mathematical thinking. Preschool classrooms have focused on mathematical concepts based on the teacher's beliefs and comfort level of mathematics (Ginsberg, Lee & Boyd, 2008). In doing so, the mathematical experiences have varied significantly from one class to another. Listening and participating in the math talk with the children would reveal the need to stimulate knowledge construction through experiences that provoke mathematical thinking.

Early education professionals should provoke children to engage with each other collaboratively within the classroom and allow them to face mathematically based problems in their world. The collaborations would stimulate conversations about solutions, further promoting mathematical knowledge construction and communication. This would provide opportunities for the children to hear different ideas that could challenge their thinking, creating mental conflict (Copley, 2000).

Enhancing the dramatic play themes in the early education classroom would stimulate additional math talk, as different themes provoke rich math talk. As noted in the findings, the children's math talk was more prevalent in four of the play themes enacted over the course of the study. Varying the play themes would expand children's math talk to incorporate other experiences that relate to mathematics.

Listening to children's math talk would allow early educators to maximize the application of young children's informal math knowledge and approximations. Strengthening young children's use of informal math knowledge would lead them to greater levels of mathematical knowledge. Purpura, Baroody and Lonigan (2013) suggest children's informal mathematics knowledge is mapped on to the formal mathematics knowledge. Therefore, a greater understanding of informal math knowledge would improve the relevance and accuracy of the early instruction of formal math knowledge.

Children's math talk should serve as a guide in planning for the methods for teaching formal mathematics, typical in the kindergarten years and beyond. Encouraging children to discuss their mathematical ideas, whether right or wrong, would stimulate conversations and create situations that provoke new understandings. Math talk should become a standard component of mathematical instruction and knowledge in children's math experiences (Fuson, Clements, Beckmann, 2010).

Parents of Young Children

Parents are the young child's first teacher and their interactions can be vital in developing mathematical knowledge. Parents, much like many early childhood educators, have often focused on promoting children's literacy and neglected opportunities for physical and logico-mathematical knowledge construction. Both literacy and mathematics are important and can be intertwined in daily activities.

Children need exposure to mathematical concepts that are beyond the basic skills of counting. Parents who exposed their children to more complex math concepts such as geometry, measurement and probability had children with higher math scores (Skwarchuk, 2009). Further, the mathematical concepts found in the children's math talk suggest children are capable of acquiring these concepts and applying them to various situations.

Further, parents should engage children in talking about math concepts they experience every day. Parents should converse with children daily about mathematical concepts to promote children's ability to make connections between math and their daily experiences (Klibanoff et al., 2006). Conversations about sorting laundry, setting the table, and measuring when cooking are simple examples of natural opportunities for math talk in the home.

Recommendations for Future Research

This study explored preschool children's math talk during their free play. The peer interactions and the provocations from the researcher revealed the purposes of the children's math talk. Upon conducting the analysis several potential areas for future research were found. The following list of recommendations is not meant to be an exhaustive one as the research possibilities in math talk are numerous.

1. The math talk included in this study was confined to the children's math talk and, therefore, did not include the teacher's math talk. Additional research is needed to examine the impact of the teacher's math talk on the children's math talk. Exploring each in isolation and then correlating the two would add to the understanding of young children's math talk.
2. The math talk observed in this study was in one classroom with little diversity among the children. Further research with diverse populations and in different settings would add to the body of research on math talk. What would be the purposes of math talk with children in a mixed-age classroom like a family

child care setting? How might the math talk vary with children from various socio-economic status backgrounds?

3. Research has shown a teacher's beliefs and comfort level in math influence the types of mathematical experiences he or she creates for the children in the classroom. Illuminating a teacher's beliefs about young children's mathematical knowledge and connecting it to the children's math talk may reveal connections that have not yet been uncovered.
4. The children in this study did not exhibit many communicated changes in their mathematical thinking. This may be due to the young age of the children, as the mean age of the ten children was only three years and two months. Future research could further examine this line of questioning with slightly older children, between three and a half and four years-old. The children at this age are more verbal and have had more experiences that may result in their communicating the changes in their thinking.

Summary of Chapter

This chapter has discussed the study findings of children's uses of math talk and communication of changes in their mathematical thinking. The researcher has shared a summary of the study, a discussion of each research question and themes as well as the implications for early education professionals and parents and recommendations for future research. The remaining components of the chapter include the limitations and final conclusions of the study.

Limitations

There were some limitations in this study. The first limitation was the age of the children included in this study. Some of the children enrolled in the classroom were younger than three years-old, which was not expected. Due to the small number of children in the classroom, younger children were added to the classroom, causing a significant age difference between the youngest and the oldest child, which was a year and two months. This brought the mean age of the children to three years and two months. The second limitation in the study was the limited diversity of the children in the classroom as all except three children were of the same ethnic and socio-economic status. The third limitation was the lead teacher's absences were more frequent than expected, which affected the researcher's role and the children's behaviors. Due to the professional role of the researcher in the center, the researcher was looked to for guidance from the substitute teachers on the instruction and routines of classroom. The fourth limitation was the researcher's professional relationship with the teacher. The teacher attempted to converse with the researcher in the midst of the observation times to point out issues of concern regarding children in the classroom.

Conclusions

This study has presented information that examines the math talk of preschool children in their free play. The research questions answered add to the research of both mathematics and early childhood by exploring both mathematical thinking and communication of young children. The math talk of the children in this study provided valuable insight into the mathematical knowledge of young children. Further, the findings suggest math talk plays a significant role in the lives of young children.

Research question one explored the uses of math talk in young children's free play. The findings revealed six ways in which young children use math talk in their everyday experiences and interactions. The first use of math talk uncovered was reinforcement of the classroom rules. The children used their math talk to remind each other of the rules and routines of the classroom, as set forth by the teacher (Schmidt & Tomasello, 2012). This involved the children monitoring the number of children allowed in a center at once. If there was a violation, the children would adamantly point out the number had been exceeded and someone needed to depart immediately. The second use of math talk was to direct and or protect the play. The children would create elaborate thematic play that was not always open to compromise. The children would determine the roles of each involved in the play through math talk, such as how many babies could be in the family play or the specific participants allowed in the play. The third use of math talk was to manage and access materials in their play. The children that had the role of manager were in a place of power and made determinations if there were enough materials to share with others, often dependent on the relationships between the children (Paulus & Moore, 2014). The children seeking access to materials would state their needs in hopes of gaining access. The fourth use of math talk was children's comparisons between people and objects. The children often reference the difference in sizes between object as well as the quantity comparisons. The fifth use of math talk was descriptions and requests. The children would describe people and things as well as make requests with math talk. The children would ask for specific quantities or shapes in their play. The sixth use of math talk was declaration statements made by the children. The children would make comments referencing mathematical context such as discussions about age or quantity. The statements made usually referred to experiences the children had outside of the classroom setting. These findings indicate children have multiple uses for math talk in their free play. Their application of mathematical thinking, as evinced through their communication, shows the practicality of mathematical knowledge in their daily experiences.

The second research question considered the ways young children communicate changes in their mathematical thinking. The data revealed two ways in which children verbalize those changes. The first approach was to share and apply knowledge. The children, when acquiring information, would take on an expert role to share the information with another child. Children also applied new knowledge of mathematical terms and vocabulary, such as shape names and concepts about capacity. The second approach was to restate an idea. The children would make comments and, upon changes in their thinking, would restate the initial comment. The children's communicated changes in their mathematical thinking, though limited, revealed processes in which this can occur.

Overall, the findings in this study contribute to the understanding of children's mathematical thinking and communication. The physical and logico-mathematical knowledge of the children was discussed and expanded in their free play. The verbal thought expressed in their interactions exposed the varied uses of math talk. Young children are busy at work processing new information and learning how it relates to different situations. These findings illuminate the purposes and intentions of young children’s math talk.

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APPENDIX A

Agency Recruitment Letter

January 6, 2014

Ms. Zem Neill, CEO
Camp Fire First Texas
2700 Meacham Boulevard
Fort Worth, Texas 76137

RE: Permission to Conduct Research Study

Dear Ms. Neill:

I am writing to request permission to conduct a research study at Camp Fire Child Development Center. I am currently a doctoral candidate at Texas Woman's University and am in the process of writing my dissertation, entitled Listening to Math Talk.

The research study will involve recording children talking about mathematics during the center free play time of the day. The recording, both audio and video, will allow me to record the interactions surrounding mathematics and analyze how the children use math talk. I will also be in the center areas to participate in their play. The research study will last approximately eight weeks. During that time, children will be observed and recorded two times per week, during the 30 minutes of center time in the morning, and 30 minutes in the afternoon. The recordings will only be used for the study. Therefore, I will be the only person with access to the recordings.

I would like to conduct the research in the two/three year old classroom in the child development center. I hope to recruit the parents of the children in the classroom to allow their child to participate in the study. Enclosed are the recruitment flyer and the parent letter that will be distributed to the parents.

Your approval to conduct the research study will be greatly appreciated. If permission is granted, please submit a signed letter of approval on the company letterhead, which I will turn in to the Institutional Review Board at Texas Woman's University.

If you have any questions, please contact me at mixoncheryl@hotmail.com or 817-307-2704.

Thank you,

Cheryl Y. Mixon, M.Ed.
Enclosures

APPENDIX B

Agency Approval Letter

Camp Fire
Light the fire within

January 8, 2014

Cheryl Mixon
533 Nuffield Lane
Crowley, Texas 76036

Dear Cheryl,

Please accept this letter as permission to conduct your dissertation research for Texas Woman's University at the Camp Fire Child Development Center. I understand your research study, entitled Listening to Math Talk, will be conducted in the two/three year old transition classroom in the center.

I am aware that you will conduct the study through video and audio taping the children during their center play time to examine the math talk. I also understand the parents will be recruited to grant permission for their children to participate in the study through an informational meeting, a parent letter and parent consent form outlining the details of the research study.

Regards,

Zem Neill

Zem Neill
CEO, Camp Fire First Texas

APPENDIX C

Recruitment Flyer

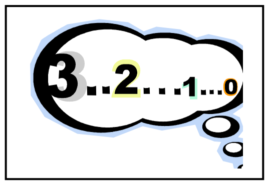
Texas Woman's University

RECRUITMENT FLYER

LISTENING TO MATH TALK

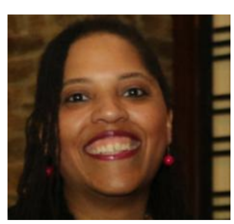
Volunteers invited to participate in dissertation research

Math concepts naturally occur as children engage in play and explore their environments. Young children talk about these math experiences regularly. Maybe your 2 year old notices his big brother has "more" candy than she does. Perhaps your 3 year old wants a bottle for each of her baby dolls. This research study will focus on this math talk.



To learn more about this exciting study and grant permission for your child to participate, please attend a parent informational meeting on May 30, 2014 from 7:45 to 8:15 am or 5:00 to 5:30 pm in the Professional Learning Classroom. If you are unable to attend the meeting, I would be happy to set an appointment to explain the research.

Researcher Contact Information



You may contact me, Cheryl Mixon, at 817-307-2704 or mixoncheryl@hotmail.com if you are unable to attend one of the meetings or have additional questions.

Eligibility	Your child must be enrolled in room 2 at Camp Fire Child Development Center
Time Frame	Beginning June 3, 2014 and continue for 8 weeks, a total of 16 hours

APPENDIX D

Cover Letter

Cover Letter

May 30, 2014

Dear Parent,

My name is Cheryl Mixon and I am the Director of the Excel Project at Camp Fire. In addition to my professional role, I am also a doctoral candidate at Texas Woman's University. I am conducting my dissertation research study, entitled Listening to Math Talk. I am writing to request permission for your child to participate in my dissertation research study.

This research study is intended to assist early childhood programs in facilitating mathematics in young children based on their talking about mathematics during their play. Gaining insight into how young children talk about mathematics will provide teachers with appropriate experiences involving mathematics.

The research study will involve video and audio recorded observations of the children's play as it relates to mathematical concepts. I will engage children in math talk by asking them questions during their play at center time. I will also make notes on the children's comments following each observation. I will visit the classroom two hours per week for eight weeks, totaling 16 hours over the entire study.

Your child's identity will not be shared, as I am the only researcher in the study. To minimize the risk of loss of confidentiality, I will create a code list with identifiers known only by me. The video recordings will be made available, as needed, to my faculty advisor and two peer reviewers. When not in use the recordings will be stored in a locked filing cabinet in my home. Risks of this study are outlined in the attached consent form. There is a potential risk of loss of confidentiality in all email, downloading and internet transactions. The entire study is voluntary and you may elect to refrain from participation at any time during the course of the study. Refraining from participation in the study will not affect you or your child's status in the classroom or in the center.

If you are interested in allowing your child to participate in the study, please read and sign the attached consent form. If you have any questions at any time, please feel free to contact me by email (mixoncheryl@hotmail.com) or by phone (817-307-2704).

Thank you,

Cheryl Y. Mixon, M.Ed.

Enclosure

APPENDIX E

Consent Form

Texas Woman's University
Consent to Participate in Research

Title: Listening to Math Talk: A Qualitative Study of Preschool Children's Math Language During Play

Principal Investigator: Cheryl Mixon mixoncheryl@hotmail.com 817/307-2704

Faculty Advisor: Dr. Karen Petty kpetty@mail.twu.edu 940/898-2685

Explanation and Purpose of the Research

The purpose of this study is to explore the math talk of preschool children. It is intended to increase the understanding of mathematical thinking and how math concepts are applied and discussed by young children. You are being asked to consent to your child's participation because he or she is currently enrolled in the 2-3 year old classroom at the Camp Fire Child Development Center. This research is to complete a doctoral dissertation at Texas Woman's University.

Research Procedures

The data sources to be gathered in this study will include observations, field notes, audio and video recorded math talk during play and photographs of the classroom environment. The data will be collected two hours each week over a period of eight weeks during center time, which is scheduled for 30 minutes in the morning and 30 minutes in the afternoon, totaling 16 hours. The researcher will be in the classroom to observe, record and interact with the children during their play in the classroom centers. The researcher will ask the children questions and make comments that are intended to provoke children's math talk as it relates to their play. Throughout this observational time, the researcher will be recording video of the children talking and interacting as they play in the centers. After each observational session, the researcher will record field notes about what occurred, focusing on the math talk captured in the videos. The video recordings of the children will be transcribed to create transcripts of the conversations and comments, which will allow the researcher to revisit how the children use their language to discuss math concepts in their play.

Potential Risk

The following is a list of potential risk that may occur over the course of the study. Confidentiality will be protected to the extent that is allowed by the law. There is a potential risk of confidentiality in all email, downloading and internet transactions. The steps to minimize the risk are also listed.

Loss of confidentiality is a potential risk in this study. To minimize this risk, all identifiable information will be translated into a code and a master list created of the codes, which will only be known by the principal investigator. This information will be stored in a locked filing cabinet in the principal investigator's home. The faculty advisor and peer reviewers will be provided with the

Approved by the Texas Woman's University Institutional Review Board
Date: 4-4-14

_____ Initial

data as needed by the researcher, which will be returned to the locked filing cabinet when they are not reviewing the data.

Loss of time The children will be observed during center time, which occurs in the morning and afternoon. The children will not be asked to stay in the center where the researcher is positioned, but they will be free to move to different centers in the classroom.

Coercion is a potential risk that may occur during the research study. To minimize this risk, parents/guardians will be informed that participation in the study is completely voluntary and if they consent to their children's participation, they may decline participation at any time during the study. This will not affect the child or parent/guardian's status at Camp Fire Child Development Center.

Loss of anonymity is a potential risk that may occur in this study. To minimize this risk, the consent forms and all discussions will occur between the researcher and the parent directly. Teachers will not be made privy to the participating children by the researcher.

Participation and Benefits

Your child's participation in this research study is completely voluntary, and you may choose to discontinue participation at any time. At the conclusion of the study the participating classroom will receive play materials that would facilitate additional math opportunities in the classroom, at a value of $50. The parents will also receive information on stimulating math talk and play with their children in the home. Parents of the participants and the teachers in the participating classroom will be invited to an informational meeting where the findings will be shared.

Questions Regarding Study

You will be given a copy of this signed and dated consent form to keep. If you have any questions about the research study you should ask the principal researcher; her contact information is at the top of this form. If you have questions about your rights as a participant in this research or the way this study will be conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

The researcher will try to prevent any problem that could happen because of this research. You should let the researcher know at once if there is a problem and she will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

____

Child Name

________________________________ ________________

Signature of Parent(s)/Guardian(s) Date

Page 2 of 2

APPENDIX F

IRB Approval Letter

TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: May 1, 2014

TO: Ms. Cheryl Mixon
Department of Family Sciences

FROM: Institutional Review Board - Denton

Re: Approval for Listening to Math Talk: A Qualitative Study of Preschool Children's Math Language During Play (Protocol #: 17646)

The above referenced study has been reviewed and approved at a fully convened meeting of the Denton Institutional Review Board (IRB) on 4/4/2014. This approval is valid for one year and expires on 4/4/2015. The IRB will send an email notification 45 days prior to the expiration date with instructions to extend or close the study. It is your responsibility to request an extension for the study if it is not yet complete, to close the protocol file when the study is complete, and to make certain that the study is not conducted beyond the expiration date.

If applicable, agency approval letters must be submitted to the IRB upon receipt prior to any data collection at that agency. A copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. Karen Petty, Department of Family Sciences
Graduate School

APPENDIX G

Parent Math Tips

Everyday Activities to Support Young Children's Mathematical Thinking

Mathematical concepts are all around us and there are many ways to apply these concepts every day. Make the most of everyday events by focusing on mathematical ideas with your child. Below are a few suggestions to get started.

- Encourage your child to separate toys or other objects into groups. For example, ask your child to separate blue toy cars from red cars or help with sorting the laundry.

- When your children get dressed, ask them to match the colors of their clothes. "Let's wear yellow today. Can you find your shirt with the yellow duck?"

- Use toys or other objects to teach your child the concepts of big and little as well as more and less. For instance, let your child play with plastic cups in the bathtub and talk about how some cups have more water in them and some have less.

- Arrange two rows of toys or other objects. Ask your child if there are more or fewer objects in the second row. Instead of counting, help your child find the answer by matching each object in the second row to an object in the first row.

- Weigh and measure your child, and tell him/her the results.

- Ask your child to count from one destination to another. For example, count from the mailbox to the door.

- Ask your children to estimate how many spoonfuls it will take to finish their cereal. Count each spoonful as they eat.

- Talk about how some things are taller or shorter and some things are lighter or heavier than your child is. Ask your child to find things in your home that are both tall and heavy or short and light.

- Help your child learn the names of such shapes as squares, circles, and triangles. Point out toys and other items in your home that have these shapes.

- Sing songs, recite rhymes, and read stories that have numbers in them—"Ten Little Monkeys: Jumping on the Bed," for example.

- Read stories that highlight groups of three, such as "The Three Little Pigs" and "Goldilocks and the Three Bears." Reading these stories gives children a sense of number groupings.

- ❖ Help your child develop a sense of time. For example, you might say, “We’ll go to the grocery this evening—after we eat dinner.”

- ❖ Be positive to help your child develop an “I can do it” attitude.