THE EFFECT OF STUDENTS' GENDER ON PRESCHOOL TEACHERS' MATHEMATIC INTERACTIONS

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A quantitative study of a convenience sample of mid-Atlantic preschool teachers was undertaken to determine if teachers use more mathematical language with males than females. I found that there was a significant difference between general mathematical interactions for females and males. Teachers used significantly more sentences with females versus males, which in turn lead to more math sentences directed at females. Additional analyses were undertaken to determine if there was a gender-based difference in the types of mathematical concepts and in how the mathematical interactions originated. This research indicates that the mathematical biases observed in elementary school teachers and parents is not present in preschool teachers or is reversed. The implications for previous studies and mathematics curriculums are discussed.

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1.0 INTRODUCTION

Science, Technology, and Mathematics have emerged as curriculums given a high level of importance and scrutiny in K-12 schools across the United States. However, interest in mathematics begins prior to primary school and is a reliable predictor of later mathematics ability (Arnold et al., 2002). Specifically, numerical competencies have been shown to predict mathematical school achievement and mathematical abilities (Krajewski & Schneider, 2009). Given the disparity between long term mathematical achievement in males and females it is important to consider how this differences may begin to manifest themselves at the earliest levels of formal education.

While some research points to diminishing achievement gaps in mathematics between the two genders (Hyde et al., 2008), data from the National Assessment of Educational Progress points to a persistent gender disparity, favoring males at fourth, eighth, and twelfth grades in mathematics (Robinson & Lubienski, 2011). Looking at data from the Early Childhood Longitudinal Study this ability gap has been documented as early as kindergarten (Robinson & Lubienski, 2011).

Regardless of whether or not there is an elementary and secondary achievement gap there is a gap in degree attainment in mathematics and related fields of study at the collegiate and professional level. Current data from the National Science Foundation (2009) indicates that women are still less likely than men to pursue a college education in the fields of math and science. Women's share of degrees in mathematics remains well below those of men and has declined since 2000 despite efforts to increase female enrollment in the field (National Science Foundation, 2010). This trend has wage implications, as individuals employed in math related careers on average earn more than their counterparts (Dey & Hill, 2007). In juxtaposition to the trends on mathematics, is the trend on overall degree attainment; as of 2013 women earned 60 percent of all master's degree and more than half of all doctoral degrees (Diprete & Buchmann, 2013).

While research has focused on teachers' gendered perceptions of ability and quantity of instruction at the elementary and middle school level (Sadker et al., 1991; Bailey, 1993; Tiedeman, 2002), few studies have looked at preschool teachers and their use of mathematics in the classroom. Existing research on possible gender stereotypes amongst preschool teachers is scarce, however, there is a body of research that points to this as possible cause for later achievement disparities. Researchers have observed gender differences in the effectiveness of mathematical curriculums at the preschool level and parental differences in the use of mathematics language amongst preschool-aged children (Arnold et al, 2002; Chang et al., 2011). Both findings are significant as research points to the importance of the preschool years as foundational for math achievement. Additionally, research indicates that the use of mathematics language within the preschool classroom can boost achievement and that achievement and interest at the preschool level are indicators of elementary school mathematics success.

Fennema (1990) points to the importance of understanding teachers' beliefs and behaviors linked to gender in understanding gender differences in mathematics. In order to begin to understand gendered instructional practices in preschool, a sample of teachers was observed and mathematical utterances directed at male and female students were identified. In addition, I coded how the interactions originated and what types of mathematics skills were being utilized with each gender.

2.0 HOW TEACHERS INFLUENCE MATHEMATICS ACHIEVEMENT

2.1 GENDER BIAS AND PERCEPTIONS

2.1.1 Preschool Studies

Studies of preschool teachers have primarily focused on their interactions with students rather than the specific academic quality of such interactions. In general, studies have found that boys receive more instructional time in preschool classrooms (Serbin et al., 1973; Cherry, 1975). Cherry (1975) found that increased contact with male students came from the need to supervise and control the boisterous behavior of boys rather than increased contact focused on planned activities or academic content. Nevertheless, this increased contact does lead to prolonged conversations with males compared to females (Serbin & O'Leary, 1975).

In a more recent study examining gender biases amongst preschool and kindergarten teachers, Saft and Pianta (2001) found that while gender correlated with different teacher metrics when combined with other ascribed factors such as age and ethnicity, it did not significantly correlate on its own. While mathematics achievement was not directly examined, Saft and Pianta examined how a child's gender relates to measurements of the teacher-child relationship. Saft and Pianta found that female gender correlated positively with positive teacher-child relationship indicators, such as closeness, and negatively with negative teacher-child relationship indicators, such as conflict. Since teachers' marks and expectations are highly correlated (Entwisle et al., 1997), favorable interpersonal ratings by teachers of female students could actually improve mathematics scores and teacher assessments of their mathematics ability.

2.1.2 Elementary and Middle School Studies

Saft and Painta's (2001) research contradicts much of the literature on teachers' perceptions related to elementary and middle school teachers, gender, and mathematics. Specifically research has found that elementary school teachers' perceptions are consistent with gender stereotypes in regards to mathematical ability (Tiedemann, 2002). In a quantitative study using surveys to capture teacher's beliefs, Tiedemann found that teachers considered males to have higher mathematical abilities than their actual grades indicated.

Additionally, elementary school teachers are more likely to have higher education expectations for boys (Hilton & Berglund, 1974). The disparity in expectations and teachers' assessment of ability has been observed in teachers from the kindergarten and up age range, indicating that gender biases manifest themselves in the classroom at an early age. Teachers' beliefs and expectations are important as they are linked to students' behaviors and perceptions of their academic self (Li, 1999).

Research indicates that these skewed perceptions and beliefs do make a difference. Teachers' beliefs are directly linked to their behaviors within the classroom (Li, 1999). Within elementary classrooms in general, research points to disparities in the quantity of interactions between teachers and students. According to Sadker and colleagues (1991), the average girl ends up with about 60 fewer hours of individual attention than the average boy over the course of a year.

An important caveat to findings of gendered interaction patterns is that across both genders teachers are more likely to interact favorably with high achieving students. However, Reyes and Fennema (1982) found that teachers interacted more often with boys who were highly confident in their math abilities than with girls who were highly confident in their math abilities. This finding would lend itself to the conclusion that even though high achieving students are receiving more attention gender stereotypes are still impacting teacher-student interactions.

2.1.3 Conflicting Conclusions on Achievement

While some research points to a nonsignificant gender gap on assessment tests (Hyde et al., 2008), others show clear and steady gaps at different time points (Robinson & Lubienski, 2011). Robinson and Lubienski cite robust national data from the main National Assessment of Educational Progress (NAEP) study and the Early Childhood Longitudinal Study (ECLS-K), as well as international data from the Trends in International Mathematics and Science Study (TIMSS), and the Program for International Student Assessment (PISA). The data they used to support gendered math disparities falls between the years of 1973-2009. Hyde and colleagues focused on data related to No Child Left Behind (NCLB) assessment tests, which they used to support the claim that there were no significant gender gaps in mathematics. Their study may indicate that gender gaps in mathematics are waning due to its more recent completion date. It could also be an indicator that gender gaps are not present across all tests.

2.1.4 Conflicting Conclusions on Gender Stereotypes

There is a body of research pertaining to gender stereotypes amongst teachers and the effects these stereotypes may have on students' assessment of their own ability, marks, and interest in mathematics, the findings as a whole are conflicting. Whether or not teachers assess students more favorably based on their gender is variable, appearing to depend on which end of the performance scale students fall on and the research metrics being used (Reyes & Fenema, 1982; Tiedmann, 2002). Preschool and kindergarten studies are less conclusive on the subject of gender-biases and how those biases may relate to achievement. I attribute this to the scarcity of research looking at gender-biases in early childhood education when compared to later schooling years.

2.2 USE OF MATHEMATICAL LANGUAGE IN THE CLASSROOM

In preschool, formal assessments (graded marks) of student achievement are uncommon. Thus it is important to begin to examine teachers' underlying beliefs and possible gender stereotypes as influences on students' early experiences with math. One teacher behavior that may reflect gendered beliefs and stereotypes is teachers' use of mathematical language with their students. Literature examining the differences in language use between the two genders by preschool teachers could not be identified. However, there is a small body of literature examining how teachers are using mathematics in the preschool classroom and the importance of utilizing mathematical language for later achievement.

2.2.1 How Preschool Teachers Utilize Mathematical Language

The amount of math-centered language teachers use is important to expanding familiarity and interest in mathematics amongst preschoolers. In a study of an assessment utilized to document preschool teachers' pedagogical content, McCray and Chen (2012) found that the amount of math-mediated language teachers used in their interviews significantly correlated with effective math teaching practices and improved child learning outcomes. Teachers who are more likely to use mathematics in their everyday speech are likely more comfortable with math concepts and more likely to use math-mediated language with their preschoolers.

An observational study conducted by Rudd, Lambert, and Satterwhite (2008) found that on average preschool teachers at a high quality center focused mainly on lower-concept mathematical orders, such as using numbers. However, they did not examine differences, if they exist, between the different genders or how the interaction originated. They did find that preschool teachers with more than four years experience were more likely to engage in higher order mathematical interactions, although these were still rare (Rudd et al., 2008). A more concerning finding may be the fact that in 40 hours of observation they did not observe any planned mathematical activities. While exposure to mathematical terms and concepts is beneficial, consciously planned activities may provide more opportunity for exposure to higher order mathematical interactions. Planned activities may also act as a barrier against stereotyping if they involve entire class participation.

2.2.2 Why Mathematical Interactions are Important

By the start of kindergarten children demonstrate wide differences in the amount of mathematical knowledge they possess (Klibanoff et al., 2006). This is particularly significant given that preschool enrollment is on the rise. In 2005, nearly 70% of 4-year-olds were enrolled in some kind of academic program, up from 16% in 1965, with the bulk of the increase coming after 1980 (Frede & Barnett, 2007). What preschool teachers are doing in the classroom has the potential to close some of the mathematical knowledge gap as children begin kindergarten.

Mathematical interaction can occur spontaneously throughout the classroom and through planned mathematical activities. As observed by Rudd, Lambert, and Satterwhite (2008) most mathematical interaction in preschool likely exists through informal activities and spontaneous interaction. According to Klibanoff and colleagues (2006) some types of input are more instructive than others but all mathematical interactions have the ability to increase children's mathematical knowledge.

In a study that included preschool classrooms serving low-, middle-, and high-SES students, Klibanoff et al. (2006) assessed children at the beginning and ending of the school year to demonstrate mathematical gains attributable to preschool instruction. They found that on average that teachers used 28.3 mathematical utterances (with a range of 1-104) within an hour of observation. Klibanoff and colleagues also found a wide variety in the types of math input used. There was a significant correlation between the general amount of math input and the diversity in types of math inputs. Perhaps the most significant finding is that the amount of mathematical input provided by a preschool teacher significantly correlated with gains made in conventional math knowledge throughout the course of the year.

Klibanoff et al.'s (2006) findings on the types of mathematical language used by teachers supports the conclusion that preschool teachers are using more passive and spontaneous mathematical interactions to incorporate mathematics into their curriculum. They found that the most commonly used type of mathematical language was cardinality followed by labeling written number symbols (Klibanoff et al., 2006). Cardinality, referring to the number of members in a set, is arguably the most basic and passive of the mathematical interactions coded as it can include statements such as, "you have two cars" with very little follow up or interaction required of the child.

2.2.3 Preschool Achievement as a Precursor to Mathematical Success

How confident and capable young children are in mathematics impacts their subsequent achievement. While there is limited research examining how effectively preschool teachers use mathematics in the classroom, and if any disparities exist between the two genders, there is a wealth of literature examining how initial mathematics achievement impacts later achievement and interest in the subject.

Mathematical ability predicts later achievement, with children who start first grade with a high level of mathematical ability showing more rapid mathematical gains through eighth grade than their peers (Williamson et al., 1991). In a robust nationwide study utilizing ECLS-K data, Bodovski and Farkas (2007) demonstrated similar results. They found that students starting kindergarten in the highest quartile for mathematics ability gained more on average from kindergarten-third grade. Mathematics gains steadily diminished from the top to bottom quartiles. These studies highlight the misconception that formal learning begins in kindergarten. For most students learning begins in the early childhood years and a significant portion of their mathematical foundation can be built in the preschool classroom in order to promote elementary school success.

A study by Duncan et al. (2007) examined large sets of national data in order to identify significant preschool predictors of elementary school mathematics success. They found that mathematics achievement at the preschool level was the strongest predictor of later achievement. Within their regression analysis they used gender as an interaction variable and found that there was not a consistent pattern of interaction between gender and other input. While gender did interact with some variables, the associations were not consistent enough to conclude that gender better positions one group over the other with other variables, such as preschool mathematics ability, held constant. Similarly, Stevenson and Newman (1986) found that mathematics achievement at the preschool level correlated with mathematics achievement in tenth grade.

2.2.4 What Math Skills Matter

Within the field of mathematics for young children there are a variety of components: number recognition, counting skills, general numeracy, equivalence, geometry, etc. A logical question is what skills really matter for later success. Basic skills such as number knowledge and counting account for a large gap between high performing and low performing kindergarteners on standardized tests (Bodovski & Farkas, 2007). While skills such as socioemotional readiness have been hypothesized to contribute to achievement, a study by Duncan et al. (2007) found that these skills as tested at the preschool level are insignificant predictors of mathematical achievement. Their study supported the claim that basic math skills matter the most, with rudimentary mathematics skills best predicting math achievement.

Conflicting studies, such as those by Krawjeski and Schneider (2009), indicate that higher order mathematical skills are more significant predictors for later mathematics success. In a study examining mathematics achievement from preschool to fourth grade in Germany, they found that quantity to number-word skills in preschool were significantly correlated with fourth grade achievement, whereas basic numerical skills were not (Krawjeski & Schneider, 2009). Quantity to number-word skills included placing a missing number (as indicated by dots on a beetle, which reveal the age of the insect) in the correct spot on a number line and being able to discuss the beetles' age in relation to the child's own age. These skills encompass cardinality and counting but also equivalence as children were requested to discuss how many beetles were older than them, how many younger, and to compare the groups. Because the study was conducted with German preschoolers there may be some disparity in results due to the differing nature of academic programs and assessments tests. However, the study points to the importance of including higher level mathematical interactions into the American preschool classroom as a measure for preparing students for kindergarten.

Data from ECLS-K may support Krawjeski and Schneider's conclusion that higher order mathematics operations are more significant predictors for later mathematics success. According to data from 1998-2000, approximately 95% of students enter kindergarten demonstrating basic number and shape skills in comparison to only 23% that demonstrate mastery over ordinality/sequence. If basic math skills, such as understanding and recognizing numbers, were most significant for predicting later success then children would enter kindergarten on a relatively even footing. The fact that there is greater disparity in a skill such as ordinality implies these higher function mathematics operations may be contributing more to the variability found in mathematics achievement.

However, it is not just what skills are taught that matters but how preschool students internalize them. In a study focused on how preschoolers respond to new mathematics curriculums, Hofer, Farran and Cummings (2013) found that gains were mediated by how often the children were observed demonstrating a focus on mathematics and the number of times they spoke during mathematics-based activities. This speaks to the need for active participation in conjunction with teachers' use of mathematical language within the classroom.

2.2.5 Mathematics Curriculums and Interventions

Klibanoff and colleagus (2006) conducted a study on types of math inputs utilized by preschool teachers and found that while some types are more instructive than others all mathematical interactions have the ability to increase children's mathematical knowledge. However, research on curriculum interventions demonstrates the impact active learning can have on mathematic ability at the preschool level. Experimental research has indicated that interventions focusing on mathematics curriculums result in higher achievement for preschoolers than those that do not actively plan math activities (Arnold et al., 2002; Brendefur et al., 2013).

Arnold et al.'s study (2002) on preschool math interventions directly questioned the concept that the efficacy of math interventions may be correlated with gender. As it was merely a lingering hypothesis, it necessitated further research into the domain of preschool mathematics and gender. In an experimental study utilizing Head Start classrooms as either the control or the treatment variable, Arnold and colleagues found that children in their math-specific intervention scored significantly higher on a post-test assessment of achievement and demonstrated more interest in mathematics. When looking at specific items of difference on the assessment counting, equivalence, and number identification were significantly different between the two groups. This may speak to the fact that a targeted math curriculum will offer more active opportunities for engagement with mathematics.

Perhaps the most important finding from the Arnold et al. study is that the effect of the intervention varied significantly by gender. Specifically, they found that boys in the experimental group exhibited a statistically significant greater change on the TEMA-2 assessment than did girls, 4.79 versus 2.77 (Arnold et al., 2002). In order to explain this result, they reexamined the activities chosen by the treatment group teachers to ensure they were varied and did not lend themselves towards preference by one gender. Finding none, they concluded that the increased attention preschool teachers pay towards male students and math-specific gender biases may have caused the difference in intervention efficacy.

My own research hopes to further Arnold and colleagues' (2002) study by examining the amount of mathematical utterances teachers direct at females versus males. If their hypothesis that the disparity in attention paid to females and males leads to gender-based differences in curriculum success is true, then I would expect to observe preschool teachers directing less general and mathematical utterances at females. In order to examine this issue in more depth, I also examined the types of mathematical utterances and how they originated for each gender.

3.0 AN ALTERNATIVE EXPLANATION FOR MATHEMATICAL ACHIEVEMENT: PARENTAL INFLUENCE

Prior to enrollment in daycare or preschool, parents are children's primary source for language and concept acquisition. Supportive and engaged parents can help bolster their child's learning, interest in mathematics, and engagement with mathematics activities in the preschool classroom. However, studies have documented that boys receive more attention and encouragement from parents regarding mathematics (Eccles et al., 2007; Chang et al., 2011).

In a study of young children, ages 14-42 months, Suriyakham, Levine, and Huttenlocher (2006) found that parental number word input was positively correlated to children's number production, counting, and cardinality. Their study focused on mathematical utterances rather than activities indicating the power of adult language use to influence preschoolers' cognitive abilities and math skills.

Chang et al. (2011) utilized data from the Child Language Data Exchange System database to systematically code for the amount of number specific speech and cardinal number speech. They found that mothers used number terms with males an average of 9.49% of utterances compared to only 4.64% with females, which was statistically significant. Furthermore mothers were significantly more likely to use cardinality with males than females, averaging 1.59% and 0.58% respectively. These differences are important given research indicating that parental language use impacts a child's ability to accurately utilize numerical vocabulary and concepts.

Parents' views of their child's ability and mathematics capability also impact children's later achievement. When examining parental attitudes over the elementary school years, Newman and Stevenson (1986) found gender-based differences in how parental attitudes correlate with children's own rankings of their ability and achievements. Specifically, female's attitudes about mathematics in tenth grade were strongly correlated to their achievement in elementary school as well as ratings of their cognitive abilities by their mothers and teachers. Interestingly, there was a favorable association between teacher assessments and later interest in mathematics and a negative association between mother assessments and later interest in mathematics. Male's attitudes towards mathematics on the other hand were correlated only with earlier achievement, indicating that females have a more complex relationship with ability, interest, and attitudinal perceptions.

Differential parental attention to mathematics demonstrates adults' inadvertent use of gender stereotyping. As similar stereotypical trends have been documented at the elementary and middle school teacher level it is crucial to determine whether or not these views are impacting preschool mathematical discussions and activities. Decreased use of mathematical language with females could be impacting their engagement with planned mathematical activities, their interest in the subject, and their later ability.

4.0 RESEARCH QUESTIONS

Previous literature, particularly that relating to the preschool classroom, has left questions regarding how teachers use mathematical language to interact with students. Some researchers argue that elementary and secondary teachers hold gender-based stereotypical views that influence their assessment of mathematics ability and effort. However, contradictory research at the preschool level may indicate that teachers actually interact with females more favorably helping to build their self-confidence and ability.

Studies that have examined parental language use have found significant differences between the amount of language used for males and females, offering an alternative explanation for why children enter kindergarten with differential mathematics ability. Since many parents now rely on formal preschools for child care and academic content, I hypothesize that some of the documented differential mathematics ability may be due to differences in language use amongst preschool teachers. Specifically, I hypothesize that preschool teachers use more mathematical language with males than females. As teacher/parent language use has been demonstrated to be significantly correlated with later math ability this finding could provide a significant reason for why achievement gaps exist even at a young age.

Questions that this study will examine are:

1. Do preschool teachers have significantly more mathematical interactions with males than females?

2. Do these interactions arise for different reasons? For example, are preschool teachers engaging more with males because of inaccuracies in their spoken mathematical language, indicating something other than gender stereotyping at play.
3. Are different types of mathematical concepts used with the different genders?

5.0 METHODS

5.1 SAMPLE AND DATA COLLECTION

In this study, I observed nine preschool teachers during an hour of their typical school day. All of the teachers were observed once, with the exception of one teacher who was called out of the room at the twenty-minute mark of the observation. This teacher was subsequently observed for forty minutes on the following day. Teachers were observed in the morning during September of 2014.

The teachers were free to plan and implement their own activities and curriculum. Observed activities ranged from typical housekeeping duties such as sunscreening children prior to outdoor play to interactive activities such as playing board games. Whole class group times were also observed where a teacher interacted with individual children but also prepared the group for a transition in activities or more generally for their school day.

The sample included a group of nine preschool teachers of varying rank at a private daycare in a major metropolitan area in the mid-atlantic. The daycare divides children into classrooms based on age. All of the teachers observed worked in classrooms that served children ages 3-5 years. The program is full day and year around. It primarily serves the needs of faculty and staff at a local university, and as a result, the majority of children were from middle or high SES families.

5.1.1 Teacher Demographics and Data

A brief survey was given to teachers at the end of their observation time in order to collect demographic data. The survey asked for information regarding the duration of their teaching career, their level of education, how comfortable they felt teaching various subjects, and the kind of professional development activities they participated in.

The teachers represented a relatively homogenous group, of the nine observed, six had obtained their bachelor's degree in Early Childhood Education, two their master's degree in the field, and one an associate's degree. Due to the small sample size (and resultant low statistical power) it was impossible to accurately discern the effects of teacher educational level on mathematical language use. Moreover, the present sample was relatively homogenous in terms of education with teachers falling at the higher end of the spectrum.

The frequency of years spent teaching was slightly more variable. Teaching experience ranged from three plus years. Experience categories were divided as follows: 0-2 years (0 teachers), 3-5 years (1 teacher), 6-8 years (1 teacher), 8-10 years (1 teacher), and 11 or more years (5 teachers). Total mathematical utterances and years employed as a teacher were not significantly correlated ($r=.080$, $p=.838$). Thus, I do not further investigate the effects of teacher experience on discourse practices.

Regarding their comfort level teaching language arts, mathematics and science; five of the teacher's indicated that they were very comfortable with all three subjects, two indicated they were only somewhat comfortable with science, and two indicated they were only somewhat comfortable with science and mathematics. Language and literacy skills were clearly the skills preschool teachers felt most comfortable teaching. However the majority of those sampled, 78%, indicated that they were also very comfortable teaching mathematics. As a result, it seems unlikely that discomfort with math is a primary reason why teachers shy away from mathematical interactions, or fail to initiate mathematics discussions and activities frequently.

The teachers sampled were highly active in professional development activities. Five types of professional activities were queried on the survey: (1) classes and training outside of the center, (2) reading professional related materials, (3) classes and trainings inside your center, (4) college courses related to your field, and (5) professional guidance from a mentor. All of the teachers sampled took part in classes and trainings both inside and outside of their center. On average the teachers participated in 3.6 different types of professional development training. The least commonly used form of professional development was “college courses related to your field,” which may just be an indicator that few of the teachers were currently pursuing a degree and that focused single trainings were preferable over semester long courses.

5.2 OBSERVATIONAL CODING OF MATHEMATICAL INTERACTIONS

In order to assess the amount of mathematical language being used by the preschool teachers their observations were recorded both via digital recorder and by hand during the observation. The digital recordings were transcribed and interactions were broken down into sentence length utterances as the basic unit of analysis. As the amount of mathematical language teachers were using was of primary importance, a technique was established to define utterances as phrases that centered on a central idea and included no more than 15 words. Fifteen words was used as a benchmark as it has been recommended as the ideal sentence length for effective communication (Markel, 2010).

To assess for differences in the amount of language used with female and male preschool children all interactions were coded as being directed towards a female, a male, or a group. All group interactions, regardless of gender composition, were coded as belonging to the group category. Language directed towards groups typically fell into one of two categories: (1) general announcements to the entire classroom, (2) sentences directed at mixed-gender groups.

5.2.1 Typology of Mathematical Interactions

The typology of mathematical interactions used in this analysis (see Table 1) was adapted from Klibanoff et al.'s (2006) study of preschool teacher's mathematical talk. A primary difference between the categories used in the Klibanoff et al. study and those used for this study lies in the determination of counting. Kilibanoff and colleagues coded questions such as, "how many trucks are you playing with?" as an instance of cardinality only. For the purposes of this study that was coded as an instance of cardinality and counting. Determining how many were in a set requires preschoolers to either count externally or internally. As such, I chose to code these sentences as cardinality and counting jointly.

Mathematical interactions could be coded to represent more than one of the nine categories. For instance the phrase, "look for the number 10 on your board" during a game of bingo would represent both cardinality and number symbols. As these examples illustrate, the majority of teacher interactions included cardinality, $M=.946$, $SD=.051$.

Table 1. Hypothetical Examples of Types of Mathematical Inputs by Teachers

Type of Input	Examples
Counting	"You have one, two, three, four bears to play with."
Cardinality	"You are eating two crackers"
Equivalence	"You each have five beads. You have the same amount."
Nonequivalence	"Three people voted for trains and five people voted for cars. Which number is bigger?"
Number Symbols	"Does anyone have a 10 on their game board?" "What number am I holding up?"
Conventional Nominative	"Today is September eighteenth."
Ordering	"Twelve, what number comes after twelve?"
Calculation	"You had three brushes and put one away, how many do you have now?"
Placeholding	"We can count using ones or tens." When breaking down the number seventy: "How many tens do we have? Seven tens."

5.2.2 Origination of Mathematical Interactions

In addition to the types of mathematical interactions used by preschool teachers *how* the interactions originated was coded. Three codes were developed: teacher initiated, child initiated, or correction. An example of a teacher initiated interaction would be one in which the child was playing or talking in a nonmathematical way and the teacher redirected him or her towards math by the use of a mathematical utterance. Child initiated, on the other hand, indicates a math utterance originating with the child. Note that preschool teachers frequently "revoice" what children say (Juzwik et al., 2013). An example would be a child that says, "I have three trucks" and a teacher who responds by reiterating the phrase. If the teacher chose to elaborate on the statement then it was coded as teacher initiated, for example, "how many trucks would you have if I gave you two?" Correction took place when a child was using mathematics improperly; for example teachers corrected errors in counting or use of a number, or promoted the student to try again.

6.0 RESULTS

6.1 RESULTS FOR OVERALL MATHEMATICAL INTERACTIONS

Table 2 reports a frequency tabulation for mathematical and non-mathematical teacher utterances by gender of student. In order to analyze the number of mathematical sentence-length utterances used by preschool teachers, I first conducted an independent samples t-test on the proportion of the 3,512 total teacher utterances directed at male or female individuals. Note that individual teachers varied considerably in the quantity of discourse observed, ranging from a minimum of 204 to a maximum of 594 utterances. Sentences directed towards females accounted for 60% of total teacher utterances (2,237 sentences were directed at females versus 1,275 sentences directed at males). A substantially higher proportion of sentences (63.7%) were directed at females ($t=-12.456, p<.001$).

During the observation process, I documented the gender of individual children teachers were interacting with as well as the total gender makeup of the classroom. However, these proportions were extremely variable, and could not be matched with precision to individual utterances. Children were arriving throughout the observation processes. Teachers and children were moving to different activities and tasks while being observed. During the observations classrooms ranged from 38% to 60% female. The range for individual activities however was different, teachers were observed spending their time with individual children, in mixed groups and in gender homogenous groups. However, the classroom range indicates that, overall, teachers had the opportunity to interact relatively evenly with both genders. I believe the higher proportion of utterances directed at females (63.7%) represents a statistical as well as practical difference. Teachers in these data were directing more of their speech at female children despite a relatively even proportion of male and female students.

A one sample t-test was run on mathematical utterances for individuals only, *N*=346, in order to address the main question of whether the amount of time spent talking about mathematics differs between female and male students. Of the 346 spoken math utterances, 228 (65.9%) were directed at females and 118 were directed at males, representing a significantly higher usage of math utterances with females ($t=-6.228$, $p<.001$). Note that, the literature on mathematical language amongst preschool teachers does not indicate a common or ideal level of math sentences within a classroom. Within this sample, non-mathematical sentences accounted for 90.1% of total sentences spoken, *CI=[.11,.09]*.

Table 2. Frequency Statistics for Non-Mathematical and Mathematical Teacher Utterances Directed at Males and Females

Gender	Non-Mathematical Utterances	Mathematical Utterances	Total
Males	1,175	118	1,275
Females	2,009	228	2,237
Total	3,184	346	3,512

In order to test whether the statistical significance in the prior test arose from the higher percentage of utterances directed towards female preschoolers, I ran a third independent samples t-test. This test analyzed mathematical utterances as a proportion of total utterances spoken. This analysis revealed that while preschool teachers address fewer mathematical utterances at males, the proportion is similar to that for females when looked at in relation to total utterances (10.0% versus 11.3%) and is not statistically significant (*MD=-.009, SE=.010, t=-.896, p=.370, CI=[-.011,.030]*).

Table 6 within Appendix A reports a summary of t-tests used to measure mathematical and non-mathematical differences in teacher utterances between males and females.

6.2 RESULTS FOR TYPES OF MATHEMATICAL INTERACTIONS

Only six of the nine types of mathematical interactions were observed in this sample: cardinality, counting, calculation, number symbols, ordering and equivalence. Table 3 reports the descriptive statistics for the different types of mathematical interactions within the subset of mathematical utterances. By far the most prevalent type of interaction was cardinality, which accounted for 320 mathematical utterances (94.6%). In the majority of cases, other types of mathematical interactions occurred along with cardinality.

Table 3. Descriptive Statistics for the Type of Mathematical Interaction within Total Mathematical Utterances

Variable	*N*	*Range per Teacher*	*M*	*SD*
Cardinality	320	9-57	.946	.051
Counting	25	1-5	.094	.065
Calculation	17	1-7	.040	.068
Number Symbol	38	1-16	.111	.187
Equivalence	3	3	.003	.008
Ordering	1	1	.002	.007

In order to analyze the difference in types of mathematical interaction within the subset of mathematical utterances between the two genders, I conducted independent samples t-tests on each observed type of interaction. Table 4 summarizes the mean differences observed between males and females for each type of mathematical interaction.

Table 4. Descriptive Statistics for Mean Differences between Males and Females in the Type of Mathematical Interaction

Variable	*N*	*Mean Difference*	*Standard Error Difference*	*Confidence Interval*
Counting	25	.010	.029	-.046, .067
Calculation	17	-.066	.025	-.115, -.017
Number Symbol	38	.091	.035	.021, .160
Equivalence	3	-.013	.011	-.034, .008
Ordering	1	.008	.006	-.004, .020

Within the six types of mathematical interactions, two were observed solely within one gender. These types were equivalence (only observed with females) and ordering (only observed with males). Of the six interaction types, only two were found to significantly vary based on gender. A substantially higher proportion of calculation interactions were observed with females (7.0% versus 1.0% for males), (*MD= -.066, SE=.025, t=-2.643, p=.009, CI=[-.115,-.017]*), while a substantially higher proportion of number symbol interactions were observed with males (17.0% versus 7.9% for females), (*MD=.091, SE=.035, t=2.570, p=.011, CI=[.021, .160]*). The results for all six types of mathematical interaction are in Table 7 within Appendix B.

6.3 RESULTS FOR ORIGINS OF MATHEMATICAL INTERACTIONS

6.3.1 Descriptives and Overall Tests for Significance

Three distinctions were made for how a mathematical interaction originated: teacher initiated, child initiated and correction. I grouped child initiated and correction together for a general comparison with teacher initiated as both of these interactions result from child initiation. Teachers initiated more mathematical utterances, $N=273$, than children, $N=73$. For analysis, teacher initiated was coded as a 1 and child initiated was coded as a 0. A one-sample t-test compared the mean to a hypothesized value of 0.5, representing equal child and teacher initiation. Teachers were significantly more likely to initiate math utterances than children, ($M=.82$, $SD=.387$, $t=15.237$, $p<.001$, $CI=[.28,.36]$).

However, this increased likelihood in teacher initiated math utterances (78.9%) is reflective of the increased likelihood in teacher initiated utterances in general (81.0%). In order to analyze the difference between teacher initiated math utterances and child initiated math utterances as a proportion of teacher initiated utterances and child initiated utterances, I conducted an independent samples t-test. When math utterances were looked at as a proportion of utterances in general, children were more likely to initiate math utterances (22.8%) than teachers (9.6%), ($t=-7.203$, $p<.001$, $CI:[-.168,-.096]$).

While children were less likely to initiate interactions with teachers in general, they were more likely to initiate mathematical interactions. This finding could be reflective of preschool teachers' tendencies to "revoice" and elucidate on what children say (Juzwik, 2013). The increase in teacher initiated utterances could decrease their likelihood to use mathematics as they strive to introduce new vocabulary with children, focus on other concepts (such as language arts or science), and prompt children to further explore their own ideas and theories. Children's higher likelihood for initiating mathematics utterances does indicate a willingness to learn and interest in mathematical concepts.

6.3.2 Origination Analysis by Gender

In order to examine the differences between the origination of the mathematical interaction by gender, I conducted independent sample t-tests for both teacher and child initiated sentences respectively. Table 5 summarizes the frequency counts for the origination types by gender. Recall that for both male and female students, about 10% of utterances directed at the student are mathematical. Yet, perhaps there might be an imbalance in mathematical utterances directed at males vs. females is we consider utterances separately by the origin of the speaker?

I conducted independent samples t-tests for teacher-initiated, child-initiated, and correction utterances to determine any possible imbalances. Among utterances initiated by the teacher and directed at males, 98 of 1,410 (7.0%) were mathematical while 175 of 1,709 (10.2%) directed at girls were mathematical. Again, I find little evidence of teacher bias (*t=-1.754, p=.079*).

Table 5. Frequency Statistics for Origination of Mathematical Utterances by Gender

Origination	Non-Math Utterances	Math Utterances	Total
Child Originated - Male	132	22	154
Child Originated - Female	188	51	239
Teacher Originated - Male	1,312	98	1,410

Table 5 (continued).

Teacher Originated - Female	1,534	175	1,709
Total	3,166	346	3,512

Additionally, I examined differences in the likelihood of males and females in initiating mathematical utterances. Child-initiated mathematical utterances were examined as a subset of child-initiated utterances as a whole and grouped by gender. As this study was to test teacher language use, a child initiated mathematical interaction would be coded if and only if a teacher responded in turn with a mathematical utterance. Among utterances initiated by a child, a similar proportion of the female (27.1%) or male initiated (16.7%) utterances were mathematical, ($t=-1.691$, $p=.092$).

A small percentage of child-initiated mathematical sentences were geared at correction of an improperly used math concept, $N=16$, and were not observed in all teachers, $N=4$. However, an interesting phenomenon would be whether or not math correction was seen more with one gender over the other. An independent samples t-test analyzing math correction as a subset of child initiated math utterances revealed that teachers used correction at the same relative frequency with males (9.5%) as females (13.7%), ($t=.094$, $p=.925$).

A summary of the independent samples t-tests is found in Table 8 in Appendix C.

7.0 DISCUSSION AND CONCLUSIONS

7.1 DISCUSSION

The results of this study contradict Arnold and colleagues' hypothesis that girls receive less teacher attention than boys, specifically in regards to mathematics (2006). When looking solely at the quantity of mathematical sentences, observed teachers were more likely to use mathematic sentences with females rather than males. When looked at as a subset of total sentences there is no longer a statistical significance; about 10% of teacher utterances are mathematical in nature, regardless of gender. Yet, this finding may be less relevant given the large baseline differences in teacher talk directed at males and females. Teachers in the sample were talking with females more often, and thus, were also directing mathematical language at females more often. While the percentages for math language may not be significantly different, females were receiving more opportunities to interact with teachers and on the subject of mathematics. Considering, the relatively even ratio of females to males within the observed classrooms, these findings appear to indicate a real preference on the part of preschool teachers in these data for interacting with girls.

Arnold and colleagues focused on specific targeted curriculum interventions within Head Start programs (2006). There is the possibility that there is a discrepancy in teacher language use between formal and informal activities (i.e. when teachers are engaged in a planned math activity they are more likely to engage with males). The finding that children were more likely to initiate math utterances than teachers supports the observational conclusion that teachers within these data were primarily using informal opportunities to engage in mathematics rather than planned activities. Planned activities would have arguably lent themselves to more teacher initiate math interactions. Follow-up studies should include observations during free play as well as planned activities to discern if there is a significant difference.

Additionally, Arnold and colleagues' study (2006) focused on Head Start programs while this study examined a private preschool that was observed to cater mostly to middle to high SES families. As a result the education levels of teachers, expectations of the director and parents, and professional development opportunities may differ. Teachers may be more aware of gender biases and be overcompensating by using mathematics more often with girls.

An alternative hypothesis is that teachers are still acting out a gender-based mathematics stereotype by utilizing more math utterances with females as a result of their beliefs that females need more math assistance and preparation than males. This hypothesis could be tested further by surveying teachers on their beliefs related to gender and math ability utilizing actual achievement scores as a reference point.

The hypothesis that preschool teachers are more likely to use mathematical interactions with males than females was also based on the findings of Chang and colleagues' 2011 study looking at the proportion of mathematics speech used by parents. The results are counterintuitive to Chang and colleagues' (2011) finding that American parents use numerical concepts with boys far more often than girls. This finding would further support the idea that additional educational training, a professional environment, and professional development may lead to different outcomes for parents versus teachers. Since parents are a primary source of knowledge for young children, the fact that gender stereotyping exists within the parent group could impact young girls' math achievement despite teacher efforts. Teacher-implemented math interventions programs may be more successful for males due to the additional math inputs males are receiving from their parents.

The two types of math interactions that were significantly different for each gender (calculation and number symbols) may provide insight into a potential gender bias. Number symbol recognition is a lower order mathematical process than calculation. In addition to spending more time talking with females in general and about mathematics it is a significant finding that one of the higher order math concepts was utilized more often with female students. Cherry's (1975) observation that preschool teachers spend more time focused on supervising male students may contribute to this finding. If the focus of teacher-male interactions is on supervision of boisterous behavior then preschool teachers may have less time to work through more difficult mathematical concepts.

7.2 CONCLUSIONS

This sample of preschool teachers used math interactions more frequently with females than males. If there is a gap in the efficacy of preschool math curriculums between females and males, as observed by Arnold and colleagues (2006), than this study would eliminate gender stereotyping on the teachers' part as the cause. The existence of gender stereotyping by American parents may be a problem as it could augment in-school learning in favor of males. Possible follow up studies could analyze the difference between parent and teacher language when engaging in the same tasks with male and female students to determine if each group interacts with the genders differently.

A larger scale study modeled after this one would be helpful as it could introduce more variability in SES served, type of preschool (private, public, religious), and level of teacher training and professional development. Introducing planned math activities during the observations would strengthen the conclusion that preschool teachers generally direct more of their math sentences towards females. There could be a disparity between formal and informal activities. Additionally, future studies should aim to control the ratio of males to females working with teachers during observations. With a larger more variable sample there may be significant differences not documented in the current study.

APPENDIX A

MATHEMATICAL INTERACTIONS T-TESTS

Table 6. Independent Samples t-tests for Overall Mathematical Interactions

Variable	*N*	*Mean Difference*	*Standard Error Difference*	*t*	*CI*
Direction of Total Sentences by Gender	3,512	-.141	.011	-12.456***	[-.153,-.119]
Direction of Mathematical Sentences Only by Gender	346	.34	.475	-6.228***	[-.21.-.11]
Direction of Mathematical Sentences by Gender as a Proportion of Total Sentences	3,512	-.009	.010	-.896	[-.030,011]

****p<.001*

APPENDIX B

MATHEMATICAL INTERACTIONS T-TESTS BY GENDER

Table 7. Independent Sample t-tests for the Differences between Males and Females in the Type of Mathematical Interaction

Variable	*N*	*Mean Difference*	*Standard Error Difference*	*t*
Cardinality	320	.016	.030	.509
Counting	25	.010	.029	.363
Calculation	17	-.066	.025	-2.643**
Number Symbol	38	.091	.035	2.570*
Equivalence	3	-.013	.011	-1.251
Ordering	1	.008	.006	1.392

*$p<.05$

**$p<.01$

APPENDIX C

ORIGINATION OF MATHEMATICAL INTERACTIONS T-TESTS BY GENDER

Table 8. T-tests for Differences between Males and Females in Origination of Mathematical Interaction

Variable	*N*	*Mean Difference*	*Standard Error Difference*	*t*	*Confidence Interval*
Teacher Initiated versus Child Initiated Sentences	3,512	.82	.387	15.237***	[.28,.36]
Child Initiated Math Sentences as a Proportion of Total	73	-.073	.043	-1.691	[-.157,.012]

Table 8 (continued).

Child Initiated Sentences by Gender					
Correction Math Sentences as a Proportion of Total Math Sentences by Gender	16	.011	.116	.094	[-.221,.242]
Teacher Initiated Math Sentences as a Proportion of Total Teacher Initiated Sentences by Gender	273	-.017	.010	-1.754	[-.036, .002]

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