PRESCHOOL PREDICTORS OF KINDERGARTEN MATH ACHIEVEMENT

BY

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Abstract

Early numeracy is beginning to gain widespread attention in early childhood education. Number sense has been identified as the premier skill which provides the foundation for the acquisition of higher order mathematical skills and concepts. However, there is little agreement on how to best promote number sense in young children. Two specific number sense practices that have been cited most are counting aloud and playing with manipulatives. The primary purpose of this study was to determine if counting aloud and playing with manipulatives during preschool do, in fact, have independent relationships with later early numeracy skills in kindergarten. The secondary purpose of this study was to compare the two relationships to determine if one is a more powerful predictor. Data from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) was employed. Sequential regression demonstrated that counting aloud is not a significant predictor when simultaneously controlling for age, SES, and sex, nor is it a significant predictor when also controlling for manipulative use. Manipulative use is a significant predictor when simultaneously controlling for age, SES, and sex, and remains significant when also controlling for counting aloud. When comparing the two behaviors, playing with manipulatives is a more important predictor of later numeracy skills than is counting aloud. Implications for preschool curriculum practices are discussed.

Introduction

The acquisition of mathematical skills is essential for success in school and in life. Duncan et al. (2007) found that early mathematical skills are more powerful than early reading skills at predicting later school success. Furthermore, some studies show numeric abilities to be more related to specific adult outcomes such as employability, occupational achievement, earned income, and employee productivity than are reading abilities (Bynner, 2004; Paglin & Rufolo, 1990; Rivera-Batix, 1992). The US Bureau of Labor Statistics has predicted that the careers with the highest growth rates will require greater mathematical proficiency (Liming & Wolf, 2008). In addition to limited school success and career opportunities, poor math skills have been associated with impulsive behavior and are linked to major social problems such as antisocial behavior (Badian & Ghublikian, 1983).

Achievement in Mathematics among American Students

Given the importance of the acquisition of mathematical skills in terms of school, career, and social outcomes, it is a good idea to examine current achievement in mathematics among students in America. The National Assessment of Educational Progress (NAEP) creates a National Report Card every few years, reporting the percentages of students attaining the following NAEP achievement levels: *Below Basic*, *Basic*, *Proficient*, and *Advanced*. The NAEP defines proficiency as being prepared for promotion to the next level of schooling (Reese, Miller, Masseo, & Dossey, 1997). The National Report Card from 2000 showed that 24% of American fourth graders and 26% of American eighth graders were at or above the Proficient level in mathematics. Thus, approximately three-quarters of American elementary students were not proficient in mathematics at the start of the new millennium.

These findings, as well as other indicators of significant underachievement of American students in both reading and math performance, spurred the federal ‘No Child Left Behind’ legislation in 2001 (No Child Left Behind [NCLB], 2003). NCLB heavily increased accountability measures required of school systems for the academic success of school age children. The NCLB legislation challenges educators to expend considerable resources to raise the performance level of their students to meet rigorous federal standards. In sum, the legislation requires that educators concentrate efforts aimed at both the reduction and prevention of academic underachievement.

Since that time, significant improvements in school age mathematic achievement levels have been made. The most recent National Report Card in 2009 showed that 39% of American fourth graders and 34% of American eighth graders were at or above the Proficient level in mathematics (NCES, 2009). While these gains are statistically significant and represent improvement, it remains that less than half of our nation’s fourth and eighth grade students can be considered proficient in mathematics.

Many school students meet with significant difficulties when learning mathematics. It has been reported that 6 to 14% of school-age children are estimated to have a specific learning disability in math (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005). According to research by Hasselbring, Goin, and Bransford (1988), general and special education students with math difficulty are similar in the number of math facts they can recall from memory at age seven. However, as students with math difficulty age, they fall further behind their non-math-difficulty peers in the ability to recall basic math facts from memory. In fact, this discrepancy increases each year between the ages eight and fourteen. More recently, investigators using data from the *Early Childhood Longitudinal Study – Kindergarten Cohort* (ECLS-K) found that kindergarten students displaying difficulties in math had significantly slower growth rates in math by fifth grade when compared to kindergarten students not demonstrating difficulties in math (Morgan, Farcus, & Wu, 2009). In other words, children are not likely to 'grow out of it' nor are they likely to benefit from 'the gift of time' when it comes to early math difficulties.

Some studies have investigated the relationship between cognitive abilities and low math achievement in school age children; conclusions have been mixed. Recently, Proctor, Floyd, and Shaver (2005) set out to illuminate the specific cognitive ability weaknesses that seemingly contribute to math weaknesses. They described previous findings as difficult to assimilate, as the operational definition of cognition has been inconsistent among different researchers. Using operational measures of the Cattell-Horn-Carroll (CHC) broad cognitive abilities as assessed by the Woodcock-Johnson III Tests of Cognitive Abilities (WJ-III COG), Proctor et al. (2005) examined the broad cognitive ability profiles of school-age children who display weaknesses in math (n = 120). The findings were unexpected and shed light on an important discovery. Roughly half of the children with weak math calculation skills demonstrated no normative cognitive weaknesses. It seems that poor math calculation skills are not principally due to underlying cognitive deficits, leading one to consider other influences such as inadequate formal instruction and non-enriching environments. It stands to reason that academic weaknesses which are not attributable to cognitive deficits are well suited for interventions that alter instruction and/or environments.

Using meta-analysis, Duncan et al. (2008) reviewed and analyzed six major longitudinal studies and found that mathematical ability at the onset of kindergarten is a strong predictor of mathematical achievement throughout elementary school. Further, early tests in mathematics were the strongest predictor of later mathematics achievement, stronger than attention skills in the classroom, cognitive abilities, social skills, and socioeconomic status. This analysis did not, however, investigate what specific learning behaviors of preschool children might positively influence mathematical abilities at the onset of kindergarten. Being that math is a cumulative subject where new skills are scaffolded from knowledge of previous skills, special attention should be given to promote the proper fundamentals of early numeracy skills, prior to kindergarten.

The current study investigates two specific learning tasks identified to enhance early mathematical skills: counting aloud and play with manipulatives. The study examines the relationship between these learning behaviors during the year prior to kindergarten entry and mathematics achievement during kindergarten. The results of this analysis can then serve to either promote or refute the recommendations that preschool programs adopt these learning behaviors into everyday practice.

Literature Review

Preschool Education and Early Childhood Initiatives

The value of the preschool years as providing the basis for later learning was first espoused in the 1960s and continues to have widespread support in early childhood (Brassard & Boehm, 2007). Unfortunately, not all children progress at the same rate or achieve the same milestones by the end of the preschool years. While the nature-nurture controversy is still debated, many agree with Zigler and Farber (1985 cited in Sattler, 2001) who explained that nature (genes) set the upper and lower limits of potential functioning, while nurture (environment) determines the specific level within the range that functioning actually falls. Given this explanation, at least some of the variation can be explained by the environments in which preschool children spend their waking hours. The National Household Education Survey reveals that roughly 75% of three- and four-year-old children were educated and looked after by someone other than their parents in 1999, with 58% of all 3- and 4-year-olds enrolled in center-based preschool programs (National Institute for Early Education Research, 2011). Center-based preschool programs include prekindergarten, day care centers, nursery schools, and Head Start. Studies show that quality preschool programs have positive long-term cognitive and emotional benefits and improve developmental outcomes for children, especially those from low-income and disadvantaged environments (National Association of Child Advocates, 2000).

In many ways, preschool can be considered a form of early intervention for academic success. The term early intervention refers to an extensive array of activities designed to improve the development of young children (Ramey & Ramey, 1998). The rationale for early intervention and prevention of potential academic difficulties is well-established (Satz, Taylor, Friel, & Fletcher, 1978). If left for the school age years, remedial programs must not only focus on the earliest gaps and lags in knowledge, but must also accelerate children's rates of learning if those children are to truly catch up to age-level expectations. It can be argued that the significant time required for true acceleration is beyond what is practical during a typical school day.

Favorable long-term academic outcomes have been documented when intervention attempts are initiated during the preschool years (Schenk, Fitzsimmons, Bullard, & Satz, 1980), when potential gaps between actual performance and age-level expectations are smaller and more manageable. In an issue brief, the National Association of Child Advocates (2000) summarized the two most robust studies of early childhood education programs, the Abecedarian Project and the High/Scope Perry Preschool Project. Both projects followed an experimental design, with random assignment comparing enrolled children with a control group of comparable children not enrolled. Investigators concluded that children who participated in either early childhood education program encountered greater success in school, scored higher on achievement tests, were less likely candidates for retention, were less likely to be involved in special education, and were more likely to graduate from high school. Furthermore, children who participated in either early childhood education program continued to encounter greater success into young adulthood. They were more likely to delay pregnancy, gain employment, attend a four-year college, and less likely to be arrested. The next section looks at some of the powerful organizations and initiatives that have influenced and shaped the landscape of early childhood education in the last 30 years.

Founded in 1926, the National Association for the Education of Young Children (NAEYC) is a powerful organization that advocates for early childhood issues by educating policy makers on the importance of high quality programs and services for all children birth to age eight. During the 1980s, early childhood education was beginning to move toward more formal instruction. In response, the NAEYC released the position statement *Developmentally Appropriate Practice in Early Childhood Programs Serving Children from Birth Through Age 8* (Bredekamp & Copple, 1986), which dramatically altered this trend. The statement vigorously opposed formalized instruction for young children, instead calling for developmentally appropriate practice (DAP). DAP consists of rich environments within which teachers serve as facilitators, not instructors, taking advantage of teachable moments that occur spontaneously rather than conducting structured lessons in an academic subject. These ideas followed a constructivist approach to education, favored by those such as Piaget and Vygotsky. As a result, formal explicit instruction in math was largely regarded as developmentally inappropriate for young children. Instead, preschool teachers were encouraged to allow young children to engage in free exploration such as play with blocks, water, or sand (Ertle et al., 2008).

Contrary to the NAEYC's views on formal instruction, research during the 1980s and 1990s began to stress the importance of creating intentional learning opportunities for young children during the preschool years (Shore, 1997). One such finding came from the Committee on Early Childhood Pedagogy. The Committee, as commissioned by the

National Research Council, issued the report *Eager to Learn: Educating our Preschoolers* (Bowman, Donovan, & Burns, 2001). This report clearly espoused that preschoolers had more learning potential than was being tapped by then-current pedagogy. Further, it contended that more rigorous early childhood teaching practices would likely result in enhanced learning in the school age years. More specifically in the early mathematics education arena, the importance of intentionally developing early numeracy skills was promoted.

The standards-based education (SBE) reform movement can be considered the vehicle for intentional teaching and learning. After the report *A Nation at Risk* was released highlighting America's failing education system, President George H. W. Bush and all 50 state governors convened at an educational summit in 1989. The summit resulted in the Senate's eventual adoption of Goals 2000: Educate America Act (P.L. 103-227). The resulting *National Education Goals* consisted of eight performance outcomes selected to be achieved by the year 2000 (see Appendix A). Schools and teachers across America were asked to align curriculum and teaching practices to set academic standards indicating what children should know, understand, and be able to perform in order to facilitate these National Education Goals. The SBE movement called for tougher, measureable standards for all students.

In an effort to promote best practices regarding mathematics teaching and learning at the preschool level, the National Council of Teachers of Mathematics (NCTM) included standards for preschool within the comprehensive set of national mathematics standards for the first time in the document titled *Principles and Standards* *for School Mathematics* (NCTM, 2000). These standards are well-steeped in appropriate teaching practices, aligning specific student mathematical expectations with developmental readiness. In a joint position statement, the NCTM and NAEYC delineated recommendations for the teaching of mathematics in the preschool environment (NAEYC/NCTM, 2002). Similar to previous NAEYC position statements, many of the previous ideals of DAP are maintained, such as rich environments and capitalizing on teachable moments. In addition, the paper endorses teacher-guided projects and experiences. However, in what is viewed as a radical change in pedagogy, the statement contends that these practices are not sufficient in and of themselves. Rather, teaching mathematics to young children needs to be based on an organized and comprehensive curriculum which introduces math concepts in a linear fashion. It seems that the NAEYC has revised their original definition of DAP, now endorsing structured curriculum and the intentional teaching of mathematics to young children.

Principles and Standards for School Mathematics groups grade levels together into four bands: pre-K-2, 3-5, 6-8, and 9-12. The new inclusion of preschool highlights the need to focus on the critical years before the onset of kindergarten. There is a common set of content standards used consistently across the grade bands: Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability. Each content standard has a set of goals that are applied to all grade bands. Then, grade bands differentiate expectations, or what children should know for each goal. The table in Appendix B of this document reflects the content standards, goals, and expectations for the pre-K-2 grade band.

These standards created by NCTM and recommendations endorsed by NAEYC represent important steps in the quest to bring the intentional teaching of early numeracy skills into the forefront of preschool education. Despite these and other concentrated efforts, not all of the goals in Goals 2000 were actualized, including the first goal which stated that all children will begin kindergarten ready to learn, and the fifth goal which stated that the United States will be first in the world in science and mathematics. In response, the National Mathematics Advisory Panel was established in 2006 to use empirical research to provide recommendations in the report titled *Foundations for Success: Final Report of the National Mathematics Advisory Panel* for expanding knowledge and improving performance of American children in mathematics. The importance of a coherent curriculum beginning in preschool through grade 8 was established, with an emphasis on critical topics in the early grades. In terms of pedagogy, the report asserts that instruction should be neither entirely student-centered nor teacher-directed, as both forms of teaching has advantages in specific situations. The report also highlights the advantages for giving young children a strong start, and simultaneously promotes the importance of strong conceptual understandings and automatic recall of facts in early numeracy.

Early Numeracy Skills

Preschool children have an intuitive, though informal, sense of numeracy and mathematical abilities (Ginsburg, Cannon, Eisenband, & Pappas, 2006) and are developmentally able to grasp more abstract and challenging mathematical concepts than previously assumed. Resnick (1989) contends that young children naturally transform their everyday experiences and understandings of quantities of materials in the physical environment into what is termed protoquantitative schemas. These schemas then become the basis for certain foundational concepts in mathematics including relative size (e.g., little, big) and part-whole understanding. Preschool teachers, therefore, have the opportunity for developing these newly identified capacities and scaffolding onto them more sophisticated mathematical competencies.

While the goal is to eventually base instruction on empirical research, the field of early numeracy is in its infancy. Information on early numeracy processes is limited compared to early literacy, but abundant scholarly activity in the last decade is growing the knowledge base rapidly. Lago and DiPerna (2010) note that the construct of number sense is difficult to operationalize, resulting in a variety of definitions. What is number sense? While the definition varies, Gersten, Jordan, and Flojo (2005) postulate that early numeracy can be summarized as a comprehensive and fluent command of number sense. Anghileri (2000) suggests that number sense is much more than procedural knowledge of mathematics. Rather, true number sense refers to developing deeper understandings and appreciations for quantity, encouraging positive attitudes toward mathematics, and inspiring confidence to engage in flexible and inventive strategies for problem solving. However, this conceptual definition of number sense makes the construct elusive to researchers.

Within the different operational definitions for number sense, some explicit tasks are identified consistently. The tasks identified with the most frequency are counting and quantification (Baker et al., 2002; Case & Sandieson, 1992; Gersten & Chard, 1999;

Howell & Kemp, 2005; Van De Walle, 1990; Van Luit, 2000). The National Mathematics Advisory Panel indicates that counting (determining exact quantity) is likely one of the best skills to build number sense, along with subitizing (quickly recognizing the total of small item sets), estimating (approximating values of large quantities), and intuitive knowledge of addition and subtraction (understanding adding on and taking away from quantities).

It seems that the conceptual definition of number sense and the operational definition of number sense are at odds. If one follows that number sense is an understanding of quantity that is beyond procedural knowledge, then why do attempts to measure number sense typically involve counting, a task of procedural knowledge? Based on the recommendation from the National Mathematics Advisory Panel, both explicit, teacher-directed tasks and implicit, student-centered tasks are important components for teaching number sense. The following paragraphs will first delve further into the explicit activity of counting, examining the procedures of learning and performing the task, as well as its empirical relevance for number sense. Next, the implicit activity of play with manipulatives will be reviewed, including a discussion of the non-procedural nature of the activity, as well as its empirical relevance for number sense.

Counting

Perhaps the most basic skill in mathematics is the ability to count. Research has pinpointed counting as an important antecedent to later mathematical skills (Geary, 1990). Although there are no controlled studies to support this, Resnick (1989) suggested that the most probable explanation for the differences seen in mathematical knowledge in young children is the frequency with which they are asked to count and quantify. She wrote,

> In environments in which exact quantification is frequently demanded, children are likely to pay more attention to numbers, to learn the number sequence sooner, and to count sets sooner…If this is so, preschool programs can foster number-concept development mainly by providing many occasions and requests for quantification… (p.164)

In their seminal work on counting, Gellman and Gallistel (1978) demonstrate how three- and four-year-old children understand the principles of counting and describe counting as the vehicle for quantification. In other words, the act of counting will lead to the ability to quantify. Counting is actually quite complex, comprised of smaller individual behaviors. It has been suggested that the acquisition of counting behaviors follows a linear, sequential pattern (D'Mello & Willemsen, 1969; Gellman & Gallistel, 1978). This researcher is attempting to organize the counting behaviors into three simple steps: labeling, one-to-one correspondence, and quantification.

Counting behavior 1: Labeling. Counting is the act of labeling one by one in order to determine the total quantity of a given set. The first behavior inherent to counting is the prerequisite need to memorize and verbally produce the conventional, ascending numeral sequence (i.e., counting aloud) (Clements, 2004). Learning the numeral sequence in order to count aloud is achieved in a similar manner as one learns general language skills such as the ABC's. This researcher argues that this skill requires direct, explicit instruction for mastery.

Counting behavior 2: One-to-one correspondence. In order to accurately count objects, children must also master one-to-one correspondence (Fuson, 1988). Although some consider counting aloud as a derivative of one-to-one correspondence, the two behaviors have been shown to be psychologically independent behaviors in terms of learning (Wang, Resnick, & Boozer, 1971). One-to-one correspondence involves the coordination of saying the memorized numeral sequence while pointing to or shifting objects, marrying each word said in time with an object touched in space (Fuson, 1988). Understandably, the coordination required for mastery of counting takes much time and practice. In a study involving 78 kindergarten students, Wang et al. (1971) asked participants to count a set of physical objects. Interestingly, most subjects did not take advantage of the opportunity to move the physical objects while counting, acting instead as if the objects were fixed. As a result, subjects were more likely to make errors in counting either by counting objects twice and/or skipping objects. This observation suggests to this researcher that explicit, intentional instruction is required to encourage children to shift objects away from the original group while counting, thereby making fewer errors.

Counting behavior 3: Quantification. The final behavior in counting is determining the total number of objects in a collection (Clements, 2004), often referred to as quantification. This final step involves making the connection between the counting of objects to discovering the quantity. For many preschoolers, the question, 'how many?' is misinterpreted as a cue to start counting rather than a request for information on how large the collection is. This researcher believes that direct, explicit instruction is often required to help children recognize that the last number counted in the sequence directly refers to how many items are in the collection. What remains unclear, however, is whether or not preschool teachers are aware of this pattern of teachable counting behaviors and if they are engaging students in numeracy activities that follow this pattern.

How counting relates to number sense. Counting behaviors are taught using explicit instruction. Similarly, early math knowledge is assessed in a manner that depends on an explicit verbal answer. For example, young children are asked to recite the numbers aloud in the correct sequence as a means to assess their numeracy knowledge (e.g., *Count to 10*.). They are asked to demonstrate their ability to quantify by saying the total (e.g., *How many blocks are on the table?*). Without proper development of the three counting behaviors as described above, two of which have a heavy verbal component, young children would have a difficult time proving their true understandings of number sense.

Jordan, Kaplan, Locuniak, and Ramineni (2007) tracked the development of number sense from the onset of kindergarten to the middle of first grade, at six points in time. The number sense battery was comprised of the following core subareas: counting, number knowledge, nonverbal calculation, story problems, and number combinations. Children (n = 277) were then given a general math assessment at the end of first grade. Results indicate that even at the onset of kindergarten, number sense was strongly correlated with math achievement at the end of first grade ($r = 0.70$, $p < 0.01$). Each of the individual core subareas was found to be significantly correlated to first grade mathematics achievement ($p < .01$) at all six data points. Interestingly, counting had the lowest correlations, with a weak to moderate relationship with later math achievement (r values ranging from .28 to .37 over six data points) while all the other subareas had strong correlations with later math achievement (r values ranging from .40 to .68). The study also controlled for background variables including income status, sex, age, and reading ability, but found that they did not add explanatory variance beyond number sense. The researchers suggest that the next step for research involves an investigation on the effects of explicit instruction in number sense on math achievement.

This study was not without limitations. The researchers investigated the development of number sense beginning in kindergarten. Given the increased attention and focus on early numeracy for young children, it seems important to investigate how number sense factors such as counting in the preschool setting are correlated with later mathematics achievement. Also, the sample used was drawn from a single school district, so caution must be applied when attempting to make large-scale generalizations.

Play with Manipulatives

Since Piaget (1962) rationalized the difference between the roles of exploration (e.g., learning about the properties of objects) and play (e.g., investigating the uses of objects), play was elevated to an important educational task. Play is widely regarded as the vehicle for children to practice and acquire skills and abilities across a variety of domains including social and emotional development, cognitive development, language development, and physical development (Sheridan, Howard, & Alderson, 2011). Play does not require explicit instruction; all children naturally play (Cerio, 2000). Therefore, play can be considered a student-centered activity.

The term ‘heuristic play’ was first used in the 1980s by researchers Goldschmeid, Macmichael, and Hughes who were investigating the play of toddlers (Hughes, 2009). A derivative from the Greek word *eurisko* meaning ‘I discover,’ heuristic play involves the act of making discoveries by observing one’s own actions of play. The term ‘manipulative’ in the mathematical realm means a concrete object that can be manipulated. Math manipulatives often include things such as counting beads, number puzzles, magnetic erector sets, building cubes (e.g., Legos), and wooden blocks.

There are several number concepts that are naturally developed through heuristic play with manipulatives (Hughes, 2009). Children as young as 10 months can begin to develop the foundational understandings of big/little, long/short, one/some/more, heavy/light, and addition and subtraction through heuristic play. These concepts are some of the same concepts of that undergird quantification, a basic behavior of counting.

History on use of manipulatives. The practice of allowing children to gain understanding of numeracy through the use of manipulatives is not a modern one. Samuel Goodrich published *The Children’s Arithmetic* in 1818 and defined our understanding of young children and their early numeracy abilities (Saracho & Spodek, 2008). Goodrich contended that rote learning and memorization of rules would only serve to prevent true understanding of arithmetic. Rather, he proposed that young children should discover the rules of number and arithmetic through the manipulation of concrete objects like bead frames and counters. Learning through discovery removed the notion that mathematics was based on memorization. This technique was considered revolutionary given that during the colonial era, it was largely assumed that children under the age of twelve were too young to understand arithmetic concepts. In fact, children did not begin formalized instruction in arithmetic until at least ten years of age. Goodrich was able to demonstrate that young children were, in fact, able to comprehend arithmetic concepts when given explicit instruction through the use of manipulatives. One could argue that Goodrich's work laid the foundation for our modern developmentally-appropriate practice for early numeracy. His techniques and teachings were used primarily in infant schools with pupils ranging in age from 18 months to 6 years and were well supported by the *American Journal of Education*. In these settings, children were said to be counting up to the millions as well as solving addition, subtraction, multiplication, and division problems with considerable proficiency.

By the 1850s, several 'experts' in early childhood, mainly physicians, condemned the practice of providing didactic training for young children outside of the home. Physicians were of the opinion that by attempting to develop the intellect of children less than six years of age, lasting and significant harm is done to both the mind and body, often leading to insanity later in life (Vinovskis, 1999). In turn, the *American Journal of Education* withdrew its support for the infant schools where Goodrich's philosophies were being actualized, and sponsors, in turn, withdrew their financial support of the infant schools (Saracho & Spodek, 2008). As a result, the 'children's arithmetic' movement disappeared and in its place, the Froebelian kindergarten took root.

Freidrich Froebel started the first kindergarten in 1837 in Germany (Saracho & Spodek, 2008). As German kindergarten teachers migrated to the US, the kindergarten movement spread. The first American kindergarten was instituted in 1856. These kindergartens were private institutions where curriculum was based on Froebel's philosophies and methods involving *Gifts* and *Occupations*. The *Gifts* were handheld manipulative apparatuses to be used in specified ways. Little attention was given to the physical properties of the apparatuses, as they served to represent more profound constructs in nature. In fact, the guiding philosophy of the Froebelian kindergarten was the investigation in the relationships between God, nature, and humanity. For example, the first set of *Gifts,* consisting of six balls of yarn of different colors, served to represent the wholeness and unity of the universe. The second set of *Gifts* consisted of a wooden sphere, cube, and cylinder which served to represent unity, opposites, and diversity. The *Occupations* were composed of paper folding, paper cutting, paper weaving, drawing, painting, and modeling with clay and served to represent the occupations of ancient people. The *Gifts* and *Occupations* allowed young children the chance to construct and analyze a variety of geometric shapes and forms. While the intention of the Froebelian curriculum was not mathematically oriented, it is likely that children learned significant amounts of mathematical knowledge incidentally through play.

In the early 1900s, growing concern over the appropriateness of the Froebelian curriculum created discontent within the kindergarten movement (Saracho & Spodek, 2008). In its place, public kindergarten programs flourished, valuing experiential learning and elevating play to a legitimate component of the curriculum. In these settings teachers did not engage in direct instruction in mathematics, instead favoring readiness-building activities and projects. For example, students might be growing a garden, counting vegetables picked each week, measuring the amount of water consumed by the plants, and graphing plant growth. Also, the wooden cubes that were originally part of Froebel's *Gifts* were replaced by larger blocks of various sizes that were designed for constructive purposes, allowing children to build an endless number of unique, intricate, sturdy structures through play.

Sheridan et al. (2011) outlined the six different types of play that develop in a predictable sequence, and is referenced in Appendix C. The fourth of the six types of play is termed Constructive Play. Sheridan et al. writes,

> …beginning with very simply block-building at about 18-20 months, presumes possession of all the aforementioned motor and sensory abilities together with increasing capacity to make use of the intellectual processes involved in recognition and retrieval of previously stored memories. Additionally, it requires ability to create preliminary 'blueprints' in the mind and realize these in practical form. This type of play grows directly out of early exploratory and manipulative play, but also implies capacity to combine early 'pure' imitation with purposeful anticipation. (p. 15)

Construction play involves product formation through the use of physical manipulatives such as blocks and similar materials. Wolfgang, Stannard, and Jones (2003) summarized the findings of Ginsburg (2000) on skills acquired through construction play including:

measuring, classifying, counting, ordering, and gaining awareness of length, width, symmetry, shape, depth, and space.

How use of manipulatives relates to number sense. According to Anghileri (2006), an understanding of number evolves from concrete experiences such as those described above, to discussion of the experiences using first informal and then formal language, to finally accurate use of mathematical symbols. More simply, it is a progression from something concrete (i.e., manipulatives), to something more abstract or mental (i.e., talking about math), to something symbolic (e.g., numerals on paper). This progression of understanding takes years to advance, in many ways similar to how speech is transferred to writing. Therefore, it is important that preschool environments be well-prepared with classroom resources that facilitate the student-centered experiences for exploring numeracy with concrete materials such as manipulatives.

It is possible that some children have better developed implicit knowledge of early numeracy than is shown by their explicit verbal language. To reduce the confounding effects of verbal skills on math ability, it would seem that investigators could use performance with manipulatives as evidence of mathematical understanding. Studies could require children to physically demonstrate strategies for finding answers, thus tapping internal mental processes at work (e.g., *Show me what happens if you have two blocks and then you get two more?*) and reducing the verbal requirements for responding. By involving manipulatives as a way to respond, researchers can look outside of what children are able to explain explicitly, focusing instead on children's implicit knowledge.

Edo and colleagues have stressed the value of play in the teaching and learning of mathematics during the preschool years (Edo, Planas, & Badillo, 2009). Others remain cautiously optimistic regarding the relationship between play and mathematical development, citing the need for longitudinal studies into the long-term effects on learning (Van Oers, 1996). Researchers have attempted to relate construction play during preschool and later mathematical achievement (Stannard, Wolfgang, Jones, & Phelps, 2001; Wolfgang, Stannard, & Jones, 2003). In a retrospective study involving three- and four-year-old preschoolers ($n = 37$), researchers attempted to establish a relationship between Lego play performance during preschool and later mathematical achievements in elementary, middle, and high school (Wolfgang et al., 2003). The independent variable, Lego play performance, was rated using the Lunzer Five-Point Play Scale, based on Piagetian theory. The low score (1) indicated the LEGOs were used without regard for their properties, while the high score (5) indicated the LEGOs were utilized with high levels of insight. The researchers cite that the Lunzer research boasts 0.91 reliability with preschool-aged children. The dependent variables measuring mathematical achievements included standardized testing, report card grades, and the number/level of mathematics courses taken in high school. Children's Lego performance during the preschool years and the later variables of report card grades and standardized testing were not significant at the third and fifth grade levels. No significance was demonstrated at the seventh grade level for report card grades; however, a clear significance was found at the seventh grade level for standardized tests. Further, all of the later variables at the middle and high school levels (i.e., number of math courses taken, number of honors math courses taken) were significant. The researchers conclude that there is a significant relationship between Lego play during preschool and later achievement in mathematics developing at the middle and high school levels, though not seen during the third and fifth grade elementary years.

The Wolfgang et al. (2003) study represents an important step in growing our understanding of the relationship between play with manipulatives in the early years and later mathematical achievement; however, the study has some limitations to consider. First, the investigators waited until participants were in third grade before examining effects on mathematics achievement. Second, the study utilized archival data from a single preschool program, thus making the findings difficult to generalize to the greater population. Finally, the study did not include a large number of participants ($n = 37$), potentially limiting the power of the findings.

Conclusions

The development of mathematical skills is an important predictor of academic, career, and social outcomes. Given that the acquisition of mathematical skills is sequential, it is imperative that special attention be focused on the earliest, foundational skills, namely early numeracy skills. A growing body of empirical research is leading the field to consider number sense as the premier aspect for early numeracy; however, there is apparent disagreement over how to promote number sense in young children. Should young children be given formal, explicit instruction in number sense during the preschool years? Alternatively, should young children be engaged in free play to naturally discover numerical properties and understandings? Perhaps the answer is ‘yes’ to both questions.

According to the National Mathematics Advisory Panel (2008), a combined approach blending teacher-directed learning activities and student-centered learning activities is best practice.

The present study examined two specific learning activities that differ in approach: counting aloud and playing with manipulatives. Jordan et al. (2007) demonstrated that counting abilities at the onset of kindergarten have a significant impact on math achievement at the end of first grade. The present study sought to confirm this relationship between early counting aloud activities and later mathematics achievement while modifying the previously mentioned limitations of the Jordan et al. study by (a) investigating the effects of counting activities performed during the preschool years, and (b) using a nationally representative sample.

Young children's play with manipulatives is typically a student-centered activity which does not involve direct instruction. Wolfgang et al. (2003) demonstrated how children's constructive play with LEGOs during preschool has a significant impact on math achievement that is not evident until seventh grade and later. The present study attempts to corroborate this relationship between play with manipulatives and later mathematics achievement while addressing the aforementioned limitations of the Wolfgang et al. study by (a) looking for significant effects on achievement earlier than third grade, (b) using a nationally representative sample, and (c) having a robust number of subjects. In sum, this study seeks to determine if and how the frequency with which preschool children count aloud and play with manipulatives predicts mathematic achievement in kindergarten.

Research questions. The questions that the present study seeks to answer are as follows:

1. Is the frequency of counting aloud behaviors during preschool significantly related to mathematics achievement in kindergarten?

2. Is the frequency of playing with manipulatives during preschool significantly related to mathematics achievement in kindergarten?

3. Is there a significant difference between the relationship that counting aloud versus playing with manipulatives has on mathematics achievement in kindergarten? If so, which behavior most positively relates to later mathematics achievement?

Method

Data from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) was used in order to examine the effects of counting aloud and playing with manipulatives during preschool on mathematics achievement during kindergarten. The ECSL-B database is maintained by the U.S. Department of Education's National Center for Educational Statistics (NCES). The ECLS-B study was designed to provide detailed information regarding children's life experiences during the formative years from birth to the onset of kindergarten. NCES selected a nationally representative sample of infants born in 2001 from 96 core primary sampling units (PSUs). A PSU is a county or county group. Additional PSUs (18) outside of the core were also used to provide access to oversampled American Indian and Alaska Native children. PSUs were largely used to help keep the financial burden associated with data collection low, as individual field agents could potentially be positioned in a single PSU for all of their data collection requirements.

Participants

The ECLS-B did not use a simple random sample design, as some children were more likely to be selected than others. Instead, the ECLS-B study used a complex, multi-stage clustered list frame sampling design to choose participants. In the first stage of the design, a stratified random sample of PSUs was selected for inclusion. The PSUs were stratified by region, percentage of minority population, median household income, and urban versus non-urban area. In some of the larger PSUs, more than one county was selected at random to represent the PSU. In the second stage of the design, a stratified random sample of births was selected using list frames. List frames were comprised of registered births (birth certificates) within the preselected PSUs and were stratified first by race/ethnicity. Subsequent samples of births were then stratified by birth weight and twin status.

The original selection consisted of nearly 14,000 infants born in 2001, which was representative of the nearly 3.9 million infants born that year. Those infants who either died or were adopted prior to the first wave of data collection were excluded from the study. Also, those infants born to mothers less than 15 years of age at the time of delivery were excluded for confidentiality and sensitivity reasons. The participating children came from diverse racial/ethnic and socioeconomic backgrounds, with intentional oversampling of Asian and Pacific Islander children, American Indian and Alaska Native children, Chinese children, twins, and low and very low birth weight children to aid in focused research within these populations.

Being that the ECLS-B is a longitudinal study, the same children were followed from birth through kindergarten. Information about these children was collected at specific points, called waves. Wave 1 data were collected at roughly 9 months of age (2001-2002). Parents of approximately 10,700 children participated in Wave 1, and direct assessments were conducted with roughly 10,200 of these children. Wave 2 data were collected at 2 years of age (2003-2004). Parents of about 9,850 children participated in Wave 2, and direct assessments were given to about 8,950 of these children. Wave 3 data were collected at 4 years of age/preschool age (2005-2006). Parents of approximately 8,950 children participated in Wave 3, and direct assessments were given to approximately 8,750 of these children. Wave 4 data were collected on all children in the fall of 2006, when nearly 75% of the children had entered kindergarten or higher. Parents of nearly 7,000 children participated in Wave 4, and direct assessments were given to about 6,900 children. Wave 5 data were collected in the fall of 2007 on those children who entered kindergarten or higher for the first time (nearly 25%), as well as those children who were repeating kindergarten from the previous wave. Parents of roughly 1,900 children participated in Wave 5, and direct assessments were given to 1,900 children. Because children entered kindergarten for the first time across both kindergarten waves, the information in the present study comes from the nearly 5,250 children who entered kindergarten in 2006 and the nearly 1,600 children who entered kindergarten for the first time in 2007.

The present study specifically captured only those children who were enrolled in a center-based preschool program during the year prior to kindergarten. Participants from the ECLS-B sample were only included if they had center-based preschool teachers who participated in the Early Care and Education Provider (ECEP) Interview for the year prior to kindergarten entry (4500 out of 6850). Any potential participant from the ECLS-B sample that did not have center-based respondents for this interview during the year prior to kindergarten entry, either due to non-enrollment in center-based care or missing data, was not included in the present study.

Data Reliability

Values produced using data from the ECLS-B are open to both nonsampling error and sampling error. Nonsampling errors are made during the collection phase and processing phase. Sampling errors, on the other hand, represent the variability of estimates due to chance and are not the result of carelessness or mistakes.

Nonsampling errors. Nonsampling errors explain the variation that is due to (a) data collection, (b) data processing, and (c) data reporting. Nonsampling errors typically involve concerns with nonresponse to items, multiple interpretations of items by respondents, responder bias, response rate differences that are impacted by the timing of the administration, and human error in data handling.

It is challenging to estimate the impact of nonsampling errors. The ECLS-B study took measures to avoid these errors and compensate for them using the following methods: field testing, laboratory testing of new items, multi-day interviewer training, certification sessions, interviewer performance monitoring, and field data quality monitoring. The child assessment data response rate was 98.6% for kindergarten 2006 and 99.4% for kindergarten 2007.

Sampling errors. The sample of children selected for the ECLS-B is but one of several potential samples of children born in 2001. It stands to reason that estimates using the ECLS-B sample may differ from potential estimates that could have been produced using a different sample of children. This type of variability is termed sampling error, as it stems from selecting a sample of children born in 2001, rather than including all children born in 2001.

Weights and standard errors. All of the estimates using this data were produced by weighting the observations. Weights adjust for the biases involved in the selection of respondents (i.e., intentional oversampling of certain populations) and also adjust for nonresponse and noncoverage. Weights are used in order to produce estimates that more accurately estimate the census totals. The weight used in the present study is WKR0, developed for the analysis of information obtained at the onset of kindergarten (i.e., kindergarten 2006 or kindergarten 2007).

The standard error provides an indication of the expected accuracy of the sample estimate as compared with the population estimate. The smaller the standard error, the more likely it is that the sample estimate is close to the population estimate. Because the ECLS-B utilized a complex sample design (clustered, list-frame design with intentional oversampling of certain populations), some data violate the assumptions that are typically made when using a simple random sample. Therefore, in addition to weighting responses, special methods were used to estimate the standard errors. A jackknife replication method using 90 replicate weights was employed to calculate nearly unbiased estimates of the standard errors of the estimates. Jackknife methods were used to estimate the accuracy of the estimates of the census percentages, means, and counts. The goal of jackknife replication is to create subsamples (replicates) repeatedly for the entire sample, compute the desired statistic for each subsample, and then use the variation in these replicate statistics to estimate the variance of the original sample statistic.

Variables

Independent variables. Two independent variables were employed: counting aloud and manipulatives. A principle component analysis (PCA) was conducted on eight items: one counting aloud item (Count Aloud), and seven potential manipulative items (Math Area Manip, Area for Blocks, Teacher Puzzles, Teacher Build, Use Geo Manip, Use Count Manip, Use Rulers) with Varimax rotation and Kaiser normalization to determine how best to build the independent variables. Two criteria were used to determine which questions would be combined to create the independent variables. First, questions must have factor loadings above .34 in order to be considered (Stevens, 2002). Second, the newly created variable must be theoretically sound. The following were the potential variables:

Counting aloud. This variable is represented by one item asked during the Early Care and Education Provider (ECEP) Interview during the year prior to kindergarten entry (Waves 3 and 4). The present study includes only the responses from center-based respondents, excluding private residence providers and family members.

- *Count Aloud: How often does {CHILD} do each of the following math activities: Count out loud?* Providers were asked to respond in one of six ways: never (coded as (0), about once a month or less (1), two or three times a month (2), once or twice a week (3), three or four times a week (4), or everyday (5).

Play with manipulatives. The following seven variables represent specific items asked about manipulatives during the ECEP Interview used during the year prior to kindergarten entry (Waves 3 and 4).

- *Math Area for Manipulatives: Does your classroom have the following interest areas or centers for activities: Math area with manipulatives?* Provider responses were coded as either no (0), yes (5), refused (RF), or don't know (DK).

- *Area for Blocks*: *Does your classroom have the following interest areas or centers for activities: Area for playing with puzzles and blocks (for example, legos)?* Provider responses were coded as either no (0), yes (5), refused (RF), or don't know (DK).
- *Teacher Puzzles*: *On average, how many times per week do you play games or do puzzles with {CHILD}?* Provider responses were set to range from 0 to 21, but interviewer could override range up to 50. Responses coded ranged from 0 to 50.
- *Teacher Build*: *On average, how many times per week do you build something or play with construction toys with {CHILD}?* Provider responses were set to range from 0 to 21, but interviewer could override range up to 50. Responses coded ranged from 0 to 50.
- *Use Geometric Manipulatives*: *How often does {CHILD} do each of the following math activities: Work with geometric manipulatives (for example, parquetry blocks, or shape puzzles)?* Providers were asked to respond in one of six ways: never (0), about once a month or less (1), two or three times a month (2), once or twice a week (3), three or four times a week (4), or everyday (5).
- *Use Counting Manipulatives*: *How often does {CHILD} do each of the following math activities: Work with counting manipulatives (things for children to count) to learn basic operations (for example, adding or subtracting)?* Providers were asked to respond in one of six ways: never (0),

about once a month or less (1), two or three times a month (2), once or twice a week (3), three or four times a week (4), or everyday (5).

- *Use Rulers: How often does {CHILD} do each of the following math activities: Work with rulers, measuring cups, spoons, or other measuring instruments?* Providers were asked to respond in one of six ways: never (0), about once a month or less (1), two or three times a month (2), once or twice a week (3), three or four times a week (4), or everyday (5).

The principle component analysis yielded three factors, as seen in Table 1. Factor 1 has high positive loadings for Use Counting Manipulatives, Use Geometric Manipulatives, Use Rulers, and Count Aloud, which together account for most of the variance (30%). Factor 2 has high positive loadings for Teacher Build and Teacher Game and represents 18% of the variance. This researcher considered factor 2 to represent actions that teachers do with students. Factor 3 has high positive loadings for Area for Puzzles and Math Area for Manipulatives and explains 13% of the variance. Factor 3 appears to represent the classroom environment. However, factor 1 requires some manipulation in order for it to make theoretical sense. By removing Count Aloud, the other variables that load together (Use Counting Manipulatives, Use Geometric Manipulatives, and Use Rulers) can be conceptualized as children using manipulatives. Therefore, this researcher determined that the counting aloud variable would be based on the single item Count Aloud, and determined that the manipulative variable would be comprised of three items, Use Counting Manipulatives, Use Geometric Manipulatives, and Use Rulers. Refer to Table 1 for specific details on this data.

Dependent variable.

Children's mathematics knowledge and skills. Scores from the ECLS-B Mathematics Test were used to estimate a child's mathematical knowledge during kindergarten. The Mathematics Test attempts to measure a range of age- and grade-appropriate skills in mathematics such as number sense, counting, basic operations, measurement, geometric shapes, pattern understanding, spatial sense, and estimation. Content experts in children's early mathematics knowledge and skills developed the test framework. Based on this framework, item pools were created by borrowing existing items from the Test of Early Mathematical Ability-3 (TEMA-3), the ECLS-K test for mathematics, and by developing new items. Once constructed, the ECLS-B conducted large scale field tests to determine the psychometric properties of the items. Field test analyses allowed for the creation of the ECLS-B Mathematics Test for Waves 3, 4, and 5. The ECLS-B preschool, kindergarten 2006, and kindergarten 2007 data are scaled together, thus allowing for comparison of scores between waves.

The ECLS-B Mathematics Test uses item-response theory (IRT) procedures. In order to lessen the burden (e.g., length, intensity), children were not administered the full assessment. Rather, children were administered an adaptive measure; not all children received the same sample of test items. Children were first given a set of routing items. Based on their performance on the routing items, children were given either the (a) low difficulty, (b) medium difficulty, or (c) high difficulty set of test items. IRT assesses patterns of right and wrong responses to estimate the approximate performance of how the children would have performed had the entire assessment been administered.

The assessment was administered to children during a home visit in the fall of children's kindergarten year. The ECLS-B Mathematics Test has a possible score range of 0 to 71.

- *Math Achievement.* Performance on ECLS-B Mathematics Test for children enrolled in kindergarten for the first time in fall 2006 during Wave 4 and children enrolled in kindergarten for the first time in fall 2007 during Wave 5.

Control variables. The present study used three control variables: age at assessment, socioeconomic status (SES), and child's sex.

Age at assessment. This variable was included as a control variable as the results of the ECLS-B Mathematics Test are shown to be sensitive to children's ages at the time of assessment. See Appendix C for more information on the impact of age differences on the ECLS-B Mathematics Test. Age at assessment was determined by the number of days between the date when the child completed the assessment and the child's date of birth. The total number of days was then multiplied by 12, divided by 365, and rounded to the nearest tenth to determine the child's age in months.

- *Age.* Age at the time of assessment for children enrolled in kindergarten for the first time in fall 2006 during wave 4 and those children enrolled in kindergarten for the first time in fall 2007 during wave 5.

Socioeconomic scale. SES was ranked from 1 (poor) to 5 (wealthy) based on household income, poverty status, father's employment status, hours worked, and annual earnings and grouped into 5 categories with each quintile assigned to about 20% of the population. Children from low-income households tend to have fewer number experiences prior to school entry and thus may be at a disadvantage when beginning to learn math in school. Previous research has shown that children from low-income households enter school with a generally low level of number sense and make few gains during kindergarten and first grade (Jordan et al., 2006; Jordan et al., 2007).

- *SES*. Quintile scores were determined for all participants in fall 2006 during wave 4.

Child's sex. Sex has been shown to have small, but reliable effects on number sense favoring boys (Jordan et al., 2006; Jordan et al., 2007). This information was retrieved from the birth certificate and later verified during the 9-month parent interview. If the parent indicated a different sex than the birth certificate, the parent information was considered most accurate.

- *Sex*. Sex of the child for all children in fall 2006 during wave 4.

Data Analysis Approach

This correlational study, using sequential regression, attempted to establish a relationship between preschool experiences with counting aloud and playing with manipulatives with later school achievement in mathematics during kindergarten, while controlling for the background variables age at assessment, SES, and sex. In the first step, children's math scaled scores at kindergarten entry (Math Achievement) were regressed on how often children count aloud in the year prior to kindergarten (Count Aloud) while controlling for background variables. In the second step, the frequency of the use of manipulatives (Manipulatives) during the year prior to kindergarten was entered. Then, the model was repeated, but with the reverse order of the independent variables, entering the background variables and frequency of manipulative use in the first step, and frequency of counting aloud in the second step.

Results

Descriptive Statistics

Basic descriptive data for the sample of roughly 4500 kindergarten students are presented in Table 2. There were roughly an equivalent number of students representing both sexes (51% male, 49% female). The mean age at the time of assessment during kindergarten was 65 months (approximately 5 years, 4 months) and the mean SES quintile was 3. On average, children in the present study counted aloud during preschool more than three to four days per week (almost every day) and worked with manipulatives during preschool less often, just over one to two days per week. The average score earned on the ECLS-B Mathematics Test at kindergarten was approximately 44 out of a possible 71 points.

Correlational Analysis

The statistical analyses were performed using SPSS for Windows. No outliers were looked for or removed, as this researcher was interested in capturing the raw relationship between math achievement and the predictive variables, counting aloud, and use of manipulatives, without intentionally manipulating the data. Correlational associations between the variables are presented in Table 3. Two variables have significant correlations with the dependent variable Math Achievement: SES and Manipulatives. The control variable SES is strongly correlated with Math Achievement ($r = .422$, $p < .001$). This relationship is expected, as SES tends to affect most academic outcomes. Students with high SES have more opportunities available in life, such as high quality medical care, nutrition, childcare, enrichment opportunities, and developmentally appropriate toys and books. Children appear to achieve more academically when given provided with the benefits that higher levels of SES affords. The predictive variable Manipulatives has a very weak, but significant correlation with Math Achievement (r = .041, $p < .01$). Interestingly, Manipulatives has significant correlations with all of the other variables in the study, with the strongest relationship being with the other independent variable, Counting Aloud. It appears that if children are regularly engaged in playing with manipulatives, they are also likely to be counting aloud on a regular basis.

Regression Analysis

Sequential regression analyses were employed to test whether counting aloud and the use of manipulatives during preschool predicts math achievement in kindergarten, beyond which may already be explained by SES, age, and sex. Table 4 contains the standardized regression coefficients (β), R^2, and change R^2 (ΔR^2). Two versions or models of the hierarchical regression were performed. In Step 1 of the first model, the control variables SES, Age, and Sex along with the predictive variable Count Aloud were entered into the equation, and the regression was significant (R = .422, $F(4, 4539)$ = 246.566, $p < .001$). This significance is principally due to the significance of SES. The variables used in Step 1 accounted for 17.9% of the variance in kindergartener's math achievement. In Step 2, Manipulatives was entered into the equation (R = .426, $F(5, 4538)$ = 201.014, $p < .001$). The addition of Manipulatives into the equation allowed the entire model to account for 18.1% of the variance seen in math achievement in kindergarten. This change is small ($R^2\Delta$ = .003), but is significant.

In the second model, the same predictive variables were utilized, but entered into the equation at different times. In Step 1 of the second model, the control variables (SES, Age, and Sex) were once again employed. This time, the predictive variable Manipulatives was entered into the equation first, and the regression was significant (R = .426, $F(4, 4539) = 250.940$, $p < .001$). The variables used in Step 1 of the second model explained 18.1% of the variance in math achievement during kindergarten. In Step 2 of the second model, Count Aloud was entered into the equation (R = .426, $F(5, 4538) = 201.014$, $p < .001$). The entry of Count Aloud into the equation did not add any additional explained variance beyond what was already accounted for by Manipulatives and the control variables.

Main Findings as Related to Research Questions

Research Question 1. In the first of the study's main findings, the frequency of counting aloud behaviors during preschool was not significantly related to mathematics achievement in kindergarten. When entered with the control variables (SES, age, and sex) during Step 1 of the first model, the entire step significantly improved the ability to predict math achievement; however, the beta indicated that counting aloud alone was not a significant contributor. Similarly, no relationship was found when counting aloud was entered second, after adjusting for the control variables and play with manipulatives in Model 2.

Research Question 2. In the second main finding, the frequency of play with manipulatives during preschool was significantly related to mathematics achievement in kindergarten. In the first model, manipulatives was added in Step 2, after entering the control variables and counting aloud. Manipulatives accounted for a small, but significant, improvement for the overall model's ability to predict math achievement. In the second model, manipulatives was entered during Step 1 along with the control variables. Here, the overall step was significant, as was the beta for manipulatives.

Research Question 3. The third main finding of the study suggested the frequency of play with manipulatives was a more important predictor than counting aloud during preschool of later math achievement in kindergarten. When both predictive variables were accounted for, only play with manipulatives demonstrated a significant, positive relationship with later math achievement. When manipulatives was entered into the regression equation after counting aloud, the beta for counting aloud was reduced from .023 to -.017, resulting in an indirect, non-significant contribution. Furthermore, the ratio of the squared beta weights for the predictive variables show that preschool play with manipulatives was almost 12.5 times more important than preschool counting aloud in predicting kindergarten math achievement.

Discussion

The primary goals of the current study were to determine if counting aloud and playing with manipulatives during preschool do, in fact, have independent relationships with later early numeracy skills in kindergarten. The secondary purpose of this study was to compare the two relationships to determine if one is a more powerful predictor. The results of this study yield important information that can be applied to preschool curricula.

Implications

As outlined above, counting is one of the tasks identified most across the field when describing the operational definition of number sense. The popularity of counting aloud during preschool is further evidenced in the descriptive statistics of this sample, as the mean frequency was reported as more than three to four times per week (almost every day). Therefore, the lack of a relationship between counting aloud and math achievement found in the present study creates some dissonance or at least raises one important question – is counting truly a component of number sense?

Perhaps the results of this study support the notion that counting aloud is truly a language task, or more directly, a vocabulary task. Most content areas have certain vocabulary that must be learned in order to convey meaningful knowledge of the content. For example, in music one must learn basic vocabulary terms for notes such as *do*, *re*, and *mi*. In science one must learn the basic vocabulary terms for the classification system such as, *kingdom*, *phylum*, and *class*. However, it seems intuitive that the knowledge of the term *re* would not necessarily enhance future performance of musical talent, just as the knowledge of the term *phylum* may not accurately predict potential scientific genius. Instead, it would seem that exposing young children to a variety of musical styles often, allowing them to explore different instruments, and facilitating games and activities that focus on pitch, notes, and tempo would foster pure early musical abilities. Likewise, exposing young children to several natural elements, allowing them to explore the natural environment, and facilitating games and activities that focus on classification systems, observations, and predictions would likely foster true early science prowess. Following this line of reasoning, numbers can be conceptualized as the language of mathematics while learning how to count aloud is a vocabulary acquisition task within the content of mathematics. Further, attempts to foster genuine early numeracy may be better focused on exposure to tangible representations of numbers and sets of objects, exploration of ratio between sets of objects (e.g. natural discovery that 3 objects is greater than 2), and games and activities that focus on early number relationships (e.g., adding on and taking away).

The direct, significant relationship found between play with manipulatives during preschool and kindergarten math achievement has several practical ramifications for research, policy, pedagogy, and parenting. First, it may serve to better define the operational definition of number sense in future research. As discussed earlier, there is little agreement as to which specific behavioral factors create number sense, with counting being one of the most utilized. The present results provide an argument that not only should play with manipulatives be employed as a critical factor of number sense, but also, perhaps, that the verbal activity of counting aloud could be excluded.

Second, the importance of play with manipulatives within the scope of early numeracy growth may lend support to a constructivist approach to early childhood education, at least in the domain of mathematics. The constructivist approach lends itself toward implicit, student-centered learning activities, where teachers are facilitators and children engage in self-discovery. Early childhood educators who remain discontent with the teacher-centered movement may use the results to argue for policy change in the early numeracy curriculum.

Third, and perhaps most important, the findings may encourage preschool teachers to increase the use of manipulatives in their classrooms. As discussed above, the mean frequency of manipulative use was slightly more than one to two days per week. Perhaps now with the significant relationship between it and later math ability identified, preschool teachers will see the value of student-centered manipulative play and increase the frequency of this practice. Further, it would be important for public policy to remain current with findings in education research. In light of this study, policy could mandate that preschool children engage in construction play with manipulatives on a regular basis (e.g., every day) for a prescribed amount of time (e.g., 15 minutes).

Finally, the results may encourage parents to provide their children with simple, basic building blocks as toys and *play with them*. Parents today understand that reading to their young child every day will foster better literacy skills. Parent-child reading is a common ritual and integrated into bedtime routines, in large part due to the golden rule of literacy – *read to your child every day*. There are public service announcements, websites, community library initiatives, even a national Read Across America holiday each year sponsored by the National Education Association, all supporting reading behaviors with infants, toddlers, and preschoolers. Upon birth of her son, this author received five separate informational flyers in the baby swag bag about the importance of reading to newborns. Other information in the bag included what reactions to immunizations look like, what to do if the newborn spikes a fever, how to burp the newborn, and when and what to feed the newborn. It is remarkable that early literacy initiatives rank among these basic care instructions. However, there was no information on how to promote early numeracy development. Perhaps as a result of this study, a new golden rule for numeracy could emerge – *the more you build, the brighter your future*. While wooden blocks do not light up, giggle when tickled, or talk using computer software, their frequent use is related to significant math achievement.

Limitations and Directions for Future Research

The limitations of the present study must be discussed. While the sample of ECLS-B participants was carefully weighted to accurately reflect US census rates, all participants were born in 2001 as part of the selection criteria. Technically speaking, the results are not generalizable to the greater population. However, this researcher does not have reason to suspect that America’s infant population in 2001 was qualitatively different than infants born the year prior or the following year. What is less clear, however, is how the general population of infants today in 2012 compares to those born in 2001 when the data were collected.

The second major limitation of this study is related to the extant nature of the data. This author had no control over what items were asked during interviews, how items were worded, or how responses were coded. There is a strong potential for nonsampling error in question interpretation due to the manner in which the questions were worded. For example, the ECEP Interview asked respondents, *How often does {CHILD} do each of the following math activities: Count out loud?* This question could be interpreted several ways. Some respondents may take this to mean any act of counting aloud, including choral responding during a calendar activity at circle time (e.g., *Class, follow my pointer as we all count up to 20.*). Other teachers might have interpreted this question as asking how often the child is asked to quantify an item set by themselves (e.g., *Elijah, count how many ducks are in the water*.) Future research could asked multiple questions regarding counting aloud practices, and perhaps focus on each of the three counting aloud behaviors (e.g., labeling, one-to-one correspondence, and quantification), as well as investigate group responses versus individual responses to counting prompts.

A third limitation of the study is related to the mean frequency of the reporting counting aloud behaviors. There does not appear to be an even distribution of values at each increment of the scale, as the mean was 4.6, with 4 representing three to four times per week and 5 representing every day. Future research may want to collapse this and create a dichotomous variable which indicates on a yes or no scale if children count aloud every day. This change might provide a more even distribution of cases.

The fourth limitation of the study is connected to the size of the sample. This study utilized a robust sample size (n = 4500) and consequently, has a great deal of power. Samples like this often find small, inconsequential relationships to be statistically significant. While the results found in the current study are statistically significant, not likely to be due to chance, the practical significance could be considered small. When manipulative use increases by one standard deviation (moves up roughly one category, such as from one to two times per week up to three to four times per week), math scores increase by .060 standard deviations, or roughly .6 of a scaled score point. It seems like a considerable effort for a potentially small payoff.

The fifth limitation to the study is the strength of one of the control variables. SES had a strong and significant relationship with math achievement in kindergarten (r = .422, $p < .001$). The present study controlled for SES and revealed that manipulative use had a significant impact on later math skills, but with a small effect size. Perhaps future research could look at these relationships using structural equation modeling so that SES could be entered first, as it is causally first, to see how it predicts manipulative use, to ultimately predict math achievement. It is possible that SES is a direct and reliable predictor of manipulative use, and if so, one could investigate the benefits of using manipulatives with children from different levels of SES.

While this study does have limitations, the findings are useful to the field of early numeracy. It appears that the frequency of use of manipulatives during preschool has a significant impact on later math achievement during kindergarten. Given that children with weaker math skills in kindergarten do not tend to catch up to their peers, it is important to look at ways to promote strong early numeracy skills prior to kindergarten. In the present study, preschool teachers reported that their students counted aloud almost every day, but this practice does not appear to have a significant relationship with later math achievement in kindergarten. Therefore, based on the finding of this study, preschool programs may want to consider a more constructivist approach to early numeracy where children are encouraged to freely play with and explore manipulatives such as blocks. This type of play allows children to naturally discover the properties of numbers and experience the differences between one, versus three, versus five, and so on. The development of number sense is significantly influenced by playing with manipulatives, and is the critical foundation of math skills, upon which more complex mathematical skills and concepts can be built.

References

Anghileri, J. (2006). *Teaching number sense*. New York, NY: Continuum.

Badian, N. A., & Ghublikian, M. (1983). The personal-social characteristics of children with poor mathematical computation skills. *Journal of Learning Disabilities,* 16, 154-157. doi: 10.1177/002221948301600304

Baker, L., Scher, D., & Mackler, K. (1997). Home and family influences on motivations to read. *Educational Psychologist, 32*, 69-82. doi: 10.1207/s15326985ep3202_2

Barbaresi, M. J., Katusic, S. K., Colligan, R. C., Weaver, A. L., & Jacobsen, S. J. (2005). Math learning disorder: Incidence in a population-based birth cohort, 1976-1982, Rochester, Minn. *Ambulatory Pediatrics*, 5, 281-289. doi: 10.1367/A04-209R.1

Bowman, B. T., Donovan, M. S., & Burns, M. S. (Eds.) (2001). *Eager to learn: Educating our preschoolers.* Washington, DC: National Academy Press.

Brassard, M. R. & Boehm, A. E. (2007). *Preschool assessment: Principles and practices*. New York, NY: The Guilford Press.

Bus, A. G., Van Ijzendoorn, M. H., & Pellegrini, A. D. (1995). Joint book reading makes for success in learning to read: A meta-analysis on intergenerational transmission of literacy. *Review of Education Research,* 65, 1-21. doi: 10.2307/1170476

Bynner, J. (2004). Literacy, numeracy, and employability: Evidence from the British birth cohort studies. *Literacy & Numeracy Studies*, 13, 31-48.

Case, R., & Sandieson, R., (1992). Testing for the presence of a central quantitative structure: Use of the transfer paradigm. In R. Case (Ed.), *The mind's staircase:*

Exploring the conceptual underpinnings of children's thought and knowledge (pp. 117-132). Hillsdale, NJ: Erlbaum.

Cerio, J. (2000). Play therapy: A do-it-yourself guide for practitioners. Alfred, NY: Lea R. Powell Institute for Children & Families.

Clements, D. H. (2004). Major themes and recommendations. In D.H. Clements & J. Samara (Eds.), *Encouraging young children in mathematics* (pp. 7-72). Mahwah, NJ: Lawrence Erlbaum Associates.

D'Mello, & Willemsen, (1969). The development of the number concept: A scalogram analysis. *Child Development, 40*(3), 681-688.

Denton Flanagan, K., & McPhee, C. (2009). The Children Born in 2001 at Kindergarten Entry: First Findings From the Kindergarten Data Collections of the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) (NCES 2010-005). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Dowker, A. D. (2001). Numeracy recovery: A pilot scheme for early intervention with young children with numeracy difficulties. *Support for Learning, 16*, 6-10. doi: 10.1111/1467-9604.00178

Duncan, G. J., Dowsett, C. J., Claessens A., Magnuson, K., Huston, A. C., Klebanov, P., & Japel, C. (2008). School readiness and later achievement. *Developmental Psychology, 43*, 1428-1446. doi: 10.1037/0012-1649.43.6.1428

Edo, M., Planas, N., & Badillo, E. (2009). Mathematical learning in context of play. *European Early Childhood Education Research Journal 17*(3): 325-341.

Ertle, B. B., Ginsburg, H. P., Cordero, M. I., Curran, T. M., Manlapig, L., & Morgenlander, M. (2008). The essence of early childhood mathematics education and the professional development needed to support it. In A. Dowker (Ed.), *Mathematical difficulties: Psychology and intervention* (pp. 59-83). San Diego, CA: Elsevier.

Fuchs, L. S., Geary, D. C., Compton, D. L., Fuchs, D., Hamlett, C. L., & Bryant, J. D. (2010). The contributions of numerosity and domain-general abilities to school readiness. *Child Development 81*(5): 1520-1533.

Fuson, K. C. (1988). *Children's counting and concepts of number.* New York, NY: Springer-Verlag.

Gellman, R., & Gallistel, C. R. (1978). *The child's understanding of number*. Cambridge, MA: Harvard University Press.

Gersten, R., & Chard, D. J. (1999). Number sense: Rethinking arithmetic instruction for students with mathematical disabilities. *The Journal of Special Education*, *33,* 18-28. doi: 10.1177/002246699903300102

Ginsburg, H. P. (2000). Children's minds and developmentally appropriate goals for preschool mathematics education. Paper presented at the AERA conference. New Orleans, LA, April 28.

Ginsburg, H. P., Cannon, J., Eisenband, J. G., & Pappas, S. (2006). Mathematical thinking and learning. In K. McCartney & D. Phillips (Eds.), *Handbook of Early Child Development* (pp. 208-229). Oxford, England: Blackwell.

Haseler, M. (2008). Making intervention in numeracy more effective in schools. In A. Dowker (Ed.), *Mathematical Difficulties: Psychology and Intervention* (pp. 225 240). San Diego, CA: Elsevier.

Hasselbring, T. S., Goin, L., & Bransford, J. D. (1988). Developing math automaticity in learning handicapped children: The role of computerized drill and practice. *Focus on Exceptional Children, 20*, 1–7.

Howell, S., & Kemp, C. (2005). Defining early number sense: A participatory Australian study. *Educational Psychology: An International Journal of Experimental Educational Psychology 25*, 555-571. doi: 10.1080/01443410500046838

Hughes, A. M. (2009). *Problem solving, reasoning and numeracy in the early years foundation stage.* New York, NY: Routledge.

Hughes, B. (1999). *A Playworker's Taxonomy of Play Types*. London: Playlink.

Hutt, C. (1976). Exploration and play in children. In J. S. Bruner, A. Jolly & S. Sylva (eds) *Play – It's Role in Development and Evolution*. New York, NY: Basic Books.

Jordan, N. C., Kaplan, D., Olah, L., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77,* 153-175.

Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade math achievement form developmental number sense trajectories. *Learning Disabilities Research & Practice, 22(1),* 36-46.

Liming, D. & Wolf, M. (2008). Job outlook by education, 2006-16. *Occupational Outlook Quarterly*, Fall 2008. Retrieved from http://stats.bls.gov/opub/ooq/2008/fall/art01.pdf

Morgan, P. L., Farkas, G., & Wu, Q. (2009). Five-year growth trajectories of kindergarten children with learning difficulties in mathematics. *Journal of Learning Disabilities*, 42, 306-321. doi: 10.1177/0022219408331037

National Association of Child Advocates (December, 2000). *Making Investments In Young Children: What the Research on Early Care and Education Tells Us*. Washington, DC: National Association of Child Advocates.

National Association for the Education of Young Children and National Council of Teachers of Mathematics (2002). *Early childhood mathematics: Promoting good beginnings. A joint position statement of NAECY and NCTM.* Washington, DC: NAEYC and NCTM.

National Center for Education Statistics (2009). *The Nation's Report Card: Mathematics 2009* (NCES 2010–451). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM.

National Institute for Early Education Research (2011). *National early education and care enrollment trends – overview.* Rutgers, The State University of New Jersey: NIEER.

National Mathematics Advisory Panel (2008). Foundations for success: Final report of the National Mathematics Advisory Panel. Washington, DC: United States Department of Education. Retrieved from http://www.ed.gov/about/bdcomm/list/mathpanel/report/final-report.pdf

No Child Left Behind (NCLB) Act of 2001, 20 U.S.C.A. § 6301 *et seq.* (West 2003).

Paglin, M. & Rufolo, A. M. (1990). Heterogeneous human capital, occupational choice, and male-female earnings differences. *Journal of Labor Economics 8*: 123-144. Retrieved from http://www.jstor.org/stable/2535301

Piaget, J. (1962). *Play, dreams and imitation in childhood*. New York, NY: Norton.

Proctor, B. E., Floyd, R. G., & Shaver, R. B. (2005). Cattell-Horn-Carroll broad cognitive ability profiles of low math achievers. *Psychology in the Schools, 42*, 1-12. doi: 10.1002/pits.20030

Ramey, C. T. & Ramey, S. L. (1998). Early intervention and early experience. *American Psychologist, 53*(1), 109-120. doi: 10.1037/0003-066X.53.2.109

Reese, C. M., Miller K. E., Masseo, J., & Dossey, J. A. (1997). *NAEP 1996 mathematics report card for the nation and the states (NCES 97-488).* Washington, DC: National Center for Education Statistics. Retrieved from http://nces.ed.gov

Resnick, L. P. (1989). Developing mathematical knowledge. *American Psychologist, 44*(2), 162-169.

Reynolds, A. J. (1995). One year of preschool intervention or two: Does it matter? *Early Childhood Research Quarterly*, *10*, 1-31. doi: 10.1016/0885-2006(95)90024-1

Rivera-Bariz, F. L. (1992). Quantitative literacy and the likelihood of employment among young adults in the United States. *The Journal of Human Resources, 27*, 313-328. Retrieved from http://www.jstor.org/stable/145737

Saracho, O. N. & Spodek, B. (2008). History of mathematics in early childhood education. In O. Saracho & B. Spodek (Eds.), *Contemporary perspectives on mathematics in early childhood* (pp. 1-20). Charlotte, NC: Information Age Publishing.

Sattler, J. M. (2001). *Assessments of children: Cognitive applications*. La Mesa, CA: www.sattlerpublisher.com.

Satz, O., Taylor, H. G., Friel, J., & Fletcher, J. M. (1978). Some developmental and predictive precursors of reading disabilities: A six-year follow-up. In A.L. Benton & D. Pearl (Eds.), *Dyslexia: An appraisal of current knowledge* (pp. 457-501). New York, NY: Oxford.

Schenk, B., Fitzsimmons, J., Bullard, P. C., & Satz, P. (1980). A prevention model for children at risk for reading failure. R.M. Knights & D.J. Bakker (Eds.), *Treatment of hyperactive and learning disordered children* (pp. 31-48). Baltimore, MD: University Park Press.

Sheridan, M. D., Howard, J., & Alderson, D. (2011). *Play in early childhood: From birth to six years* (3rd ed.). New York, NY: Routledge.

Shore, R. (1997). *Rethinking the brain: New insights into early development*. New York, NY: Families and Word Institute.

Snow, C. E., Burns M. S., & Griffon, P. (Eds.) (1998). *Preventing reading difficulties in young children, National Research Council*. Washington, DC: National Academy Press. Retrieved from www.nao.edu.readingroom/books/prdyc/

Stevens, J. P. (2002). *Applied multivariate statistics for the social sciences*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Van De Walle, J. (1990). *Elementary school mathematics, teaching developmentally*. Reading, MA: Addison-Wesley.

Van Luit, J., & Schopman, E. (2000). Improving early numeracy of young children with special educational needs. *Remedial and Special Education 21*, 27-40. doi: 10.1177/074193250002100105

Van Oers, B. (1996). Are you sure: The promotion of mathematical thinking in the play activities of young children. *European Early Childhood Education Research Journal 4*(1), 71-89.

Van Oers, B. (2010). Emergent mathematical thinking in the context of play. Educ Stud Math 74: 23-37. doi: 10.1007/s10649-009-9225-x

Vinovskis, M. A. (1999). *History and educational policymaking*. Washington, DC: Library of Congress Cataloging-in-Publication Data

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wolfgang, C. H., Stannard, L. L., & Jones, I. (2003). Advanced constructional play with LEGOs among preschoolers as a predictor of later school achievement in mathematics. *Early Child Development and Care 173*(5), 467-475. doi: 10.1080/0300443032000088212

Table 1

Rotated Component Matrix of Variables for Sample of Students in ECLS-B

Variable	Component 1	Component 2	Component 3
Use Count Manip	**.775**	.051	-.074
Use Geo Manip	**.737**	.113	-.097
Use Rulers	**.622**	.133	-.035
Count Aloud	**.514**	.022	-.138
Teacher Build	.120	**.899**	-.011
Teacher Puzzle	.115	**.897**	-.023
Area for Blocks	.004	-.023	**.871**
Math Area Manip	-.298	-.008	**.675**

Note. Bold indicates a loading >.34.

Table 2

Descriptive Statistics for the Variables Across the Current Sample of Kindergarteners

Variable Name	Scale Range	Mean	Std. Dev.
Dependent Variable			
1. Math Achievement	0 - 71	44.44	10.32
Background Variables			
2. SES	1 - 5	3.23	1.42
3. Age in Months		65.03	3.77
4. Sex	0 - 1	.49	n/a
Independent Variables			
5. Count Aloud	0 - 5	4.62	.87
6. Manipulatives	0 - 5	3.38	1.20

Table 3

Intercorrelations among Study Variables

Variables	1	2	3	4	5	6
1. Math Achievement	---					
2. SES	.422***	---				
3. Age	.011	.008	---			
4. Sex	.018	-.013	-.002	---		
5. Count Aloud	.017	.016	-.057***	.016	---	
6. Manipulatives	.041**	-.026*	-.049**	.025*	.460***	---

Note. *** Correlation is significant at the <.001 level (1-tailed); ** Correlation is significant at the .01 level (1-tailed); * Correlation is significant at the .05 level (1-tailed).

Table 4

Sequential Regression for Variables Predicting Kindergarten Math Achievement

	Model 1 - Step 1		Model 1 - Step 2		Model 2 - Step 1		Model 2 - Step 2	
Predictors	β	SE	β	SE	β	SE	β	SE
SES	.422**	.098	.424**	.097	.423**	.097	.424**	.097
Age	.008	.037	.009	.037	.010	.037	.009	.037
Sex	.023	.278	.022	.277	.022	.277	.022	.277
Count Aloud	.011	.160	-.017	.180	---	---	-.017	.180
Manipulatives	---	---	.060**	.131	.052**	.116	.060**	.131
R^2	.179		.181		.181		.181	
ΔR^2	.179**		.003**		.181**		.000	

Note. $N = 4500$; $^{**}p < .001$

Appendix A

Goals 2000: Educate America Act *National Education Goals*		
1	School Readiness	All children in America will start school ready to learn.
2	School Completion	The high school graduation rate will increase to at least 90 percent.
3	Student Achievement & Citizenship	All students will leave grades 4, 8, and 12 having demonstrated competency over challenging subject matter including English, mathematics, science, foreign languages, civics and government, economics, arts, history, and geography, and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our Nation's modern economy.
4	Teacher Education & Professional Development	The Nation's teaching force will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students for the next century.
5	Mathematics & Science	United States students will be the first in the world in mathematics and science achievement.
6	Adult Literacy & Lifelong Learning	Every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
7	Safe, Disciplined, & Alcohol- & Drug-Free Schools	Every school in the United States will be free of drugs, violence, and the unauthorized presence of firearms and alcohol and will offer a disciplined environment conducive to learning.
8	Parental Participation	Every school will promote partnerships that will increase parental involvement and participation in promoting the social, emotional, and academic growth of children.

Appendix B

NCTM Principles and Standards for Mathematics

	Goal	Pre-K-2 Expectations
Number and Operations	Understand numbers, ways of representing numbers, relationships among numbers, and number systems	• Count with understanding and recognize "how many" in sets of objects • Use multiple models to develop initial understandings of place value and the base-ten number system • Develop understanding of the relative position and magnitude of whole numbers and of ordinal and cardinal numbers and their connections • Develop a sense of whole numbers and represent and use them in flexible ways, including relating, composing, and decomposing numbers • Connect number words and numerals to the quantities they represent, using various physical models and representations • Understand and represent commonly used fractions, such as ¼, ⅓, and ½
	Understand meanings of operations and how they relate to one another	• Understand various meaning of addition and subtraction of whole numbers and the relationship between the two operations • Understand the effects of adding and subtracting whole numbers • Understand situations that entail multiplication and division, such as equal groupings of objects and sharing equally
	Compute fluently and make reasonable estimates	• Develop and use strategies for whole-number computations, with a focus on addition and subtraction • Develop fluency with basic number combinations for addition and subtraction • Use a variety of methods and tools to compute, including objects, mental computation, estimation, paper and pencil, and calculators
Algebra	Understand patterns, relations, and functions	• Sort, classify, and order objects by size, number, and other properties • Recognize, describe, and extend patterns such as sequences of sounds and shapes or simple numeric patterns and translate from one representation to another • Analyze how both repeating and growing patterns

		are generated
	Represent and analyze mathematical situations and structures using algebraic symbols	• Illustrate general principles and properties of operations, such as commutativity, using specific numbers • Use concrete, pictorial, and verbal representations to develop an understanding of invented and conventional symbolic notations
	Use mathematical models to represent and understand quantitative relationships	• Model situations that involve the addition and subtraction of whole numbers, using objects, pictures, and symbols
	Analyze change in various contexts	• Describe qualitative change • Describe quantitative change
Geometry	Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships	• Recognize, name, build, draw, compare, and sort two- and three-dimensional shapes • Describe attributes and parts of two- and three-dimensional shapes • Investigate and predict the results of putting together and taking apart two- and three-dimensional shapes
	Specify locations and describe spatial relationships using coordinate geometry and other representational systems	• Describe, name, and interpret relative positions in space and apply ideas about relative position • Describe, name and interpret direction and distance in navigating space and apply ideas about direction and distance • Find and name locations with simple relationships such as "near to" and in coordinate systems such as maps
	Apply transformations and use symmetry to analyze mathematical situations	• Recognize and apply slides, flips, and turns • Recognize and create shapes that have symmetry
	Use visualization, spatial reasoning, and geometric modeling to solve problems	• Create mental images of geometric shapes using spatial memory and spatial visualization • Recognize and represent shapes from different perspectives • Relate ideas in geometry to ideas in number and measurement • Recognize geometric shapes and structures in the environment and specify their location
Measureme	Understand measurable attributes of objects and the units, systems, and processes of measurement	• Recognize the attributes of length, volume, weight, area, and time • Compare and order objects according to these attributes • Understand how to measure using nonstandard

		and standard units • Select an appropriate unit and tool for the attribute being measured
	Apply appropriate techniques, tools, and formulas to determine measurements	• Measure with multiple copies of units of the same size, such as paper clips laid end to end • Use repetition of a single unit to measure something larger than the unit • Use tools to measure • Develop common referents for measures to make comparisons and estimates
Data Analysis and Probability	Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them	• Pose questions and gather data about themselves and their surroundings • Sort and classify objects according to their attributes and organize data about the objects • Represent data using concrete objects, pictures, and graphs
	Select and use appropriate statistical methods to analyze data	• Describe parts of the data and the set of data as a whole to determine what the data show
	Develop and evaluate inferences and predictions that are based on data	• Discuss events related to students' experiences as likely or unlikely
	Understand and apply basic concepts of probability	(Intentionally Blank)

Appendix C

Average Mathematic Scale Scores for Children Born in 2001 as They Enter Kindergarten for the First Time: 2006-07 and 2007-08

Age at Assessment	Average Mathematics Scale Score	Standard Error
Less than 5 years old	38.3	1.35
5 years old to 5 ½ years old	40.8	0.34
More than 5 ½ years old to 6 years old	45.5	0.27
More than 6 years old	48.9	0.49

Note. Statistics were obtained from *The Children Born in 2001 at Kindergarten Entry: First Findings from the Kindergarten Data Collections of the ECLS-B* by Denton Flanagan & McPhee (2009).

Appendix D

Typology of Play

Type of Play	Description
Active play	Sitting, crawling, standing, running, climbing, jumping, throwing, kicking, catching
Exploratory and manipulative play	Manipulation of everyday objects such as rattles, dolls, balls, building blocks, boxes, hand toys
Imitative play	Reflects what a child sees and hears in environment
Constructive play	Block-building play with grows directly from early exploratory and manipulative play
Make-believe play	Intentional invention of increasingly complex pretend situations
Games with rules	Full understanding of sharing, turn-taking, fair play, and accurate recording of outcomes

Note. This table was originally summarized in Sheridan et al. (2011).

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Education

ALFRED UNIVERSITY – Alfred, NY
Psy.D. (2012) in School Psychology

ROBERTS WESLEYAN COLLEGE – Rochester, NY
M.S. (2004), C.A.S. (2005) in School Psychology

STATE UNIVERSTIY OF NEW YORK AT GENESEO – Geneseo, NY
B.S. (1997) in Elementary Education

Professional Experience

Instructor 1/2012 – Present
WINTHROP UNIVERSITY – Rock Hill, SC
Teach courses to undergraduate and graduate students majoring in education using a variety of teaching methodologies. Collaborate with faculty in developing a new core curriculum. Courses taught include:

- The Psychology of the Learner (EDUC 210)
- Educational Psychology & Assessment (EDUC 604)

Visiting Instructor 8/2009 – 12/2011
ALFRED UNIVERSITY – Alfred, NY
Taught courses to graduate students in school psychology (specialist and doctoral programs), school counseling, and licensed mental health counseling programs using a variety of teaching methodologies. Provided supervision to counseling students on practicum and internship in schools and community-based mental health settings. Collaborated with faculty in developing a new program leading to licensure in mental health counseling (LMHC) in New York State. Courses taught include:

- Foundations of Interpersonal Effectiveness (PSYC 636)
- Advanced Seminar: Preschool and Early Childhood (PSYC 687)
- Norm-Referenced Testing – I (PSYC 627)
- Social-Emotional Assessment (PSYC 629)
- Child Interventions (PSYC 472)
- Principles of Counseling (COUN 636)
- Advanced Counseling Theory (COUN 638)
- Practicum I (COUN 657)
- Topics in Counseling (COUN 695)

School Psychologist 2007 – 2009
SOUTHERN HUNTINGTON COUNTY & MIFFLIN COUNTY SCHOOL DISTRICTS – Lewistown, PA

Provided counseling and school psychological services to two rural school districts with an emphasis at the K-6 grade levels. Facilitated all Committee of Special Education (CSE) meetings and Child Study Team (CST) meetings for assigned schools in both districts. Key accomplishments include:

- Created and implemented Child Study Team practices for two school districts, motivating teachers and administrators to consider alternative, research-based interventions to use with students demonstrating academic and/or behavioral difficulties.
- Founding member of the Response to Intervention (RtI) team in the Mifflin County School District appointed to develop a pilot program designed to meet the diverse learning needs of all students.

Graduate Student Clinician 2005 – 2006

LEA R. POWELL INSTITUTE FOR CHILDREN AND FAMILIES – Alfred, NY

Provided mental health services to young children and families using individual play therapy techniques and family therapy methods.

School Psychologist Intern 2004 – 2005

GATES-CHILI CENTRAL SCHOOL DISTRICT – Rochester, NY

Provided counseling and school psychological services in a suburban school district at the K-12 levels. Worked collaboratively on a team of 12 school psychologists and gained experience as a contributing member of a Child Study Team.

Elementary Teacher 2000 – 2003

ROCHESTER CITY SCHOOL DISTRICT – Rochester, NY

Taught core academic subjects in an inclusive 5^{th} grade classroom in an urban school district. Implemented tiered planning and teaching with students learning at individual instructional levels. Collaborated with special education staff to provide appropriate instruction, modifications, and interventions to students in both special education and general education programming. Appointed as Teacher Representative on two administrative committees: School-Based Planning Team and Interviewing and Hiring Committee.

Parent Counselor 1998 – 2000

CHILD CARE COUNSEL, INC. – Rochester, NY

Consulted with parents on issues related to early childhood and family dynamics. Provided referrals to licensed and registered child care centers and private providers. Taught continuing education courses to child care providers on a variety of topics including appropriate discipline and behavioral interventions. Calculated feasibility studies for entities wanting to start new child care centers. Designed original web-presence for the organization to expand range of services offered to the community.

PROFESSIONAL CREDENTIALS

School Psychologist, Provisional Certification in New York State

School Psychologist, Provisional Certification in the Commonwealth of Pennsylvania

Elementary Teacher, Provisional Certification in New York State

AFFILIATIONS

American Psychological Association (APA)
American Counseling Association (ACA)
National Association of School Psychologists (NASP)
Board Member of the Wellsville Montessori School (WMS)

PROFESSIONAL SCHOLARSHIP

- Doctoral Fellow – One of nine recipients of a fully-funded federal Leadership Grant preparing school psychologist to provide leadership in the use of collaborative processes in early childhood education in rural schools (*Grant Award # H325D030057-O5* United States Department of Education; Office of Special Education Programs).
- Lead Author – Poster titled *Evaluation of Rural Preschool Programming for Children with Disabilities along the Collaborative and Ecological Continua* presented at the 116th Annual Convention of the American Psychological Association, Boston, MA; August 2008.
- Contributing Author – Poster titled *Family Processes in School-Based Mental Health Services* presented at the 116th Annual Convention of the American Psychological Association, Boston, MA; August 2008.
- Lead Author – Poster titled *A Descriptive and Formative Evaluation of Rural Preschool Programming for Children with Disabilities* presented at the 115th Annual Convention of the American Psychological Association, San Francisco, CA; August 2007.
- Contributing Author – Poster titled *Perceptions of School Staff Regarding Sexual Minority Youth* presented at the 115th Annual Convention of the American Psychological Association, San Francisco, CA; August 2007.
- Contributing Author – Paper titled *The Curious Virtue of Humility: One Effort to Measure Humility* presented at the 2nd Annual Mid Winter Research Conference of the American Psychological Association Division 36, Loyola College, MD; March 2004
- Co-facilitated an in-service training titled *FACES-IV: Improvements and Use* hosted by the Lea R. Powell Institute for Children and Families for practicing clinicians and graduate student clinicians.
- Facilitated an in-service training titled *WISC-IV: Introduction and Overview of Use* to the Gates Chili School District school psychological staff on the cognitive measure WISC-IV.

Specialty Trainings Attended: ECLS-B Database Training; Pacific Crest Teaching Institute for Higher Education; Backwards Design Curriculum Writing; Wilson Reading Program; Summer Science Institute Inquiry-Based Learning