PRESCHOOL CHILDREN'S ACQUISITION OF MATHEMATICAL COMPETENCIES

by

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Abstract

If all adults are shaped by their experiences, as most research suggests they are, then when and what children learn about mathematics will affect their attitudes and aptitudes as adults. Mathematical competency prior to kindergarten is a relativity new area of emphasis for educators and researchers. However, patterns of positive growth are beginning to emerge for children who experience rich mathematical content prior to kindergarten. This paper examines research on the extent to which early mathematics may impact young children's potential math skills. Preschool age children who experience an environment in which adults challenge and scaffold deep mathematical concepts tend to develop a foundation that increases their potential for later mathematical achievements.
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CHAPTER I

Introduction

Statement of the problem

In the preschool years children use informal mathematics intuitively to explore and make sense of their world (National Association, 2008). Children compare size, shape and classify objects as they work and play, using math for activities such as balancing a block tower, sharing cookies, as well as a variety of other activities as they make sense of their world. By testing and retesting theories and formulating hypotheses, children begin to develop concepts of truths; for example: *making one end of the ramp higher will make the cars go down faster* and *three cookies are always more than two cookies*. Truths that can be tested over and over again, yielding the same results, emerge as predictable and dependable patterns which serve as a springboard for more complex theories to be tested. As children's cognitive skills increase, they find patterns that help them to solve problems, make predictions, and generate solutions. Once they have learned the patterns of tested theories, they begin to apply previously learned information to new problems. The complexity of their new theories is built from previously learned information (Ginsburg, Lee, & Boyd, 2008). The more information they have learned, the more complex will be their later discoveries (Shore, 1997). As children move into elementary school, understanding basic conventions of informal mathematics provides a foundation from which they will begin to learn formal math (National Association, 2008).

Historically, in early childhood programs the emphasis had been on literacy (Sarama, 2004). Longitudinal research has indicated that young children who have experienced language rich environments during the first five years of life often develop larger and more functional vocabularies and acquire high levels of reading (Burns, 2002; Epstein, 2009; Golinkoff, 2000;
Zigler, 2004). Larger and more functional vocabularies provide a foundation from which children are able to comprehend increasingly more complex and abstract concepts (Shore, 1997) and solve more complicated problems. Baroody (2000) and Klibanoff (2006) also indicated that children who enter kindergarten with high levels of mathematical knowledge maintain high levels of mathematical skill throughout elementary school. Researchers are making the case for increasing the attention paid to early math which may be equally as significant as early literacy for young children's school readiness (Baroody, 2000; Klibanoff, 2006). In the U.S. about seventy percent of all four-year-old children attend a preschool or day care for one or more years before entering kindergarten (National Center for Education Statistics, 2008). An increase the opportunities for a stronger foundation of mathematics for as many as seventy percent of children before they enter kindergarten could have a rippling effect for math achievements throughout elementary school. The standards for preschool, which are the equivalent of grade level benchmarks in the K-12 system, are only recommendations at the preschool level. Children can enter kindergarten when they meet the legal age requirements regardless of their readiness to succeed.

Early learning experiences, whether in preschool, day care or home, affect later achievement (Hart, 1995, National Association, 2008, Albert Shanker, 2009). Providing a strong foundation of mathematical concepts during the preschool years is likely to increase a child's potential for acquiring and using higher level math in later life (National Science, 1996). Instruction and assessment of math competency typically does not play a major role in early childhood curricula or teacher preparation programs, despite the existence of recommended early learning math standards in almost every state (Brenneman, 2009). Recently, researchers have noted that the rigor with which academic content is delivered in preschool varies widely and is
likely correlated to the wide variety of teacher preparation programs (Albert Shanker, 2009; Lamy, 2005). Given that early experiences impact later achievements, (Shore, 1997) it makes sense that early math achievements will impact later math achievements. If we accept the assumption offered by Shore, (1997), Sarama (2004), Aunola (2004) and others who put forth the belief that all experiences, positive or negative, shape the abilities of our potential, theoretically, positive experiences with mathematical concepts will influence our mathematical abilities and attitudes. This is not to assume that we can make everyone a mathematical genius if we provide early math experiences, but we are likely to increase the potential for higher achievements if we provide a foundation from which to build. People naturally seek things which bring them pleasure, and avoid things which cause them pain (Trelease, 1979/2001). If early in life children learn to enjoy math they will see to use it more, thus building on the foundation of the preschool years.

The number of states now funding preschool for at-risk and disadvantaged three-and-four-year-old children has increased in the last decade providing an opportunity to influence the foundations of mathematics for large numbers of children before kindergarten entry (National Association, 2008). As a result of the increase in participation in preschool, it makes sense that teachers should be taught to instruct from a mathematical perspective, to make formative and summative evaluations of children's mathematical skills, and to embed "math talk" (Klibanoff, 2006) into daily routines. Preschool programs with strong math components could provide children with competent math skills as they enter kindergarten and improve opportunities for future mathematics learning (Brenneman, 2009). A challenge faced by those who support the increase in math in preschool becomes the adequate preparation of early childhood teachers (Albert Shanker, 2009; National Association, 2008). According to Ginsberg (2008), university
Mathematics pedagogy course requirements for early childhood teachers are rare. Consequently, teachers entering the field of early childhood are unprepared to meet the demands of reforms which focus on academic outcomes for preschool children, especially in the area of mathematics.

An investment in mathematical instruction during the preschool years is likely to yield long reaching benefits for children's math competencies as they progress through the education system (Albert Shanker, 2009; Brenneman, 2009). Duncan (2007) found strong associations between early academic skills and later school achievements. Specifically found were statistically significant correlations between early math skills and later math achievement and of particular interest was the consistent predictive power of early math skills assessments. "With an average standardized coefficient of .34, school-entry math skills are most predictive of subsequent achievement outcomes, followed by reading skills (.17) and attention-related measures (.10)" (p.1439). Ginsberg, Lee, and Boyd (2008) reported that achievement scores for mathematical skills may begin to show gaps as early as kindergarten, suggesting that the cognitive antecedents for acquiring mathematical concepts may be one area preschool curricula needs to address. Since mathematical skills progress from basic knowledge and rote retrieval of facts to constructs of mathematical equations for problem solving in a simple to complex hierarchy, it seems appropriate that the foundation of math aptitudes and attitudes begin early in a child's life.

The National Council of Teachers of Mathematics (NCTM, 2001) suggested that young children's abilities for mathematics begins long before they entry kindergarten. The NCTM for the first time emphasized the need to strengthen the math concepts at the preschool level in a report released in 2000. Citing research from Copley (1999) Ginsberg (2008) and Baroody (2000), NCTM focused on three concepts which are the foundation for mathematical knowledge:
matching and one to one correspondence, sets and classification, and order and seriation. Children who have opportunities to develop an understanding of these three key concepts before they begin formal mathematics appear to grasp and apply formal complex mathematical concepts more quickly than those who do not demonstrate understanding (Bhargava & Kirova, 2002). Generally, preschool math is though of as rote counting or patterning; however, Brenneman (2009) found that young, even pre-verbal children have more sophisticated understanding of mathematical concepts than previously believed. Young children apply intuitive informal mathematics from a very early age, and there is evidence (Aunola, 2004, Ginsburg, Lee, & Boyd, 2008, Sarama, 2004) that young children hold concepts, such as grouping, in their minds as early as two years old. The mental representation of numbers and the application of number value, lays the ground work for later understanding of more complex concepts (Perry, 2007). Perry indicated children's use of early informal mathematics may help children develop a mathematical approach to problem solving which could last through out life suggesting that investing in early mathematics is justifiable.

While the National Council of Teachers of Mathematics emphasizes that pre-kindergarten children need opportunities to deepen and expand their mathematical knowledge, there is no agreement on a mathematics curriculum or teaching approach for preschool children. The work of Piaget, Vygotsky, Erikson and other child development theorists have long influenced how adults work with young children. The evolution of theories and the influence of researchers have settled the majority of preschool curricula on a constructivist paradigm which provides the theoretical framework for preschool environments and instructional strategies. In typical early childhood classrooms a developmentally appropriate environment is one in which children are provided opportunities to explore and manipulate objects test and retest theories and construct
knowledge. Developmentally appropriate teaching strategies imply that environments have multiple sources and choices from which children can gain information and advance their understanding of concepts. Any infusion of academic concepts into early childhood education curriculum, it would stand to reason, should also be taught in developmentally appropriate ways. The assessment of a young child's mathematical competencies should include multiple sources of evidence about child's understanding of concepts. The National Council of Teachers of Mathematics and the National Council for the Education of Young Children jointly recommend an environment for young children in which materials, assessments and resources provide an opportunity for young children to develop a deep understanding of mathematics in order to promote a good mathematical beginning (National Association, 2008). The gap lies in a systematic teacher preparation program that facilitates the alignment of recommended math standards, developmentally appropriate instructional strategies, and assessment of mathematical competencies, in other words a math based curriculum.

Research Questions

What is the extent to which the amount and type of mathematical instruction in preschool provides lasting effects for later mathematical achievements? How should early childhood educators appropriately increase preschool children's experiences with formal and informal mathematical concepts?

The National Association for the Education of Young Children and the National Council of Teachers of Mathematics in a jointly released position statement called for research based teaching practices, policies, supports and resources for teachers to effectively deliver high quality mathematical experiences for young children (National Association, 2008). The position
statement claimed that early experiences in math allow children to advance math skills at a faster rate and to do more complicated math than children without high quality early math experiences, supporting the need for mathematics in preschool. Academic content, specifically mathematics, has been viewed by early childhood professionals as secondary to the main purpose of socio-emotional competencies (Woods, 2009). Recently, several research projects have surfaced that indicate preschool children are capable of learning complex academic concepts and learning is sustainable throughout the child's academic life, this research included mathematical concepts (Albert Shanker, 2009; Copley, 1999; Duncan, 2007; Ginsburg, et al., 2008; Perry, 2007).

Demands to produce academic outcomes for children attending state or federally funded preschool programs, coupled with the increasingly available research indicating lasting effects of early mathematics, are supporting the inclusion of math in preschool.

Baroody (2000) noted during an observation of preschool children, the use of reasonably complex math during every day play. During the observations, Baroody went on to note that the experiences appeared to be cumulative, and children naturally transferred previously learned information to novel and more complex situations. The teacher's ability to observe and scaffold the learning through direct and indirect instruction during natural play situations was a key to substantial differences in the children's transfer of knowledge. Without support and reinforcement from adults who are keenly aware of mathematical progressions children's errors cannot be redirected and environments cannot be manipulated to increase the complexity of the problems (Baroody, 2000).

How children transfer math concepts learned during natural play situations into useful problem solving situations is not well documented but Bhargava and Kirova (2002) noted that the transfer of knowledge is the crux of successful mathematics achievement. Accurate
documentation of children's skills is dependent on teachers' understanding of the emergent
sequence of math concepts (Epstein, 2009). Teachers who have not received competent training
in mathematics and child development may have limited understanding for alignment and
scaffolding of mathematics concepts and children's developmental learning processes. A lack of
understanding may lead to inadequate assessment of children's skills, inadequate manipulation of
the environment and missed opportunities to scaffold children's learning. Mathematical
competencies are acquired in a sequential fashion, teachers who understand the psychology of
math development will be more effective in teaching and assessing children's knowledge
(Aunola, 2004).

Millions of young children attend preschool and daycare settings daily, the opportunity to
increase the mathematical competencies with the same rigor as we have attacked emergent
literacy exist. The research on mathematics instruction for preschool children is far from
complete; however the growing body of research provides promising outcomes for math
achievement for preschool children and beyond (National Association, 2008).
Chapter II- Review of Literature

Over the last twenty-five years, preschool programs have become more available and more popular (National Association, 2008). Although the most universally accepted curriculum frameworks are strongly supported by research, the specific content of the curriculum remains a debated subject. The Head Start Reform Act of 2002 enacted legislation that shifted the focus of Head Start from social skills to academic outcomes which prepare children to enter school ready to learn. The legislation cited research that supported the need for academic standards with an emphasis on literacy and math. Consistent with the Head Start Reform Act, the National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) issued policies and recommendations calling for more rigorous academic content in preschool (Duncan, 2007; National Council, 2001; National Association, 2008). These two policy recommendations have ignited the recent shift from social skills to academic skills in preschool programs. Some maintain that preschool experiences should continue to focus only on the broad constellation of social skills, such as group behaviors, attention span, interest in learning, friendship skills, and leave the academic content to kindergarten teachers (Duncan, 2007). The divide has sparked research and continued the debate about the definition of school readiness, the extent to which preschool skills predict academic achievements later in school, and the extent to which specific skills sets learned at the preschool age provide long term effects. The pressure of No Child Left Behind has added to the need for academic outcomes; the legislation calls for all children being prepared to enter kindergarten ready to learn. In a review of the literature most cited by the Head Start Reform Act, the NAEYC and the NCTM, three main research projects surfaced: Duncan (2007), Ginsburg (2008) and Klibanoff (2006). Duncan (2007) analyzed six longitudinal data sets to identify associations
between academic skills, social behaviors and later school success. The comparative analyses of six studies included the *Early Childhood Longitudinal Study-Kindergarten Cohort (ECLS-K)*, the *National Longitudinal Survey of Youth (NLSY)* the *Study of Early Childhood Care and Youth Development (SECCYD)*, the *Infant Health and Development Program (IHDP)*, the *Montreal Longitudinal-Experimental Preschool Study (MLPS)* and finally the *British Birth Cohort Study (BCS)*. To measure the associations between early academic skills, social-emotional behaviors and later school achievements, Duncan used a set of regression models across all data sets, evaluating data collected on slightly less than thirty-seven thousand children over a twenty-five year period of time. Duncan used a meta-analysis then treated regression coefficient as an equation to summarize the associations between early indicators and later skills. Duncan and his colleagues predicted that there would be a pattern of characteristics which could be associated with later patterns of achievement. In other words, they looked at children who were successful in academic achievements in grades five, six and seven, went back to data collected prior to high achieving children entering kindergarten, and looked for patterns of common indicators. The researchers looked for links between three key elements of school readiness: academic skills, attention skills and socio-emotional skills. The criteria use by Duncan for the selection of the studies included diversity of population representation, a wide set of readiness and achievement indicators and a method to isolate variables. The data was on children between birth and fourteen years of age and included achievement test, teacher and parent reports and isolation of variables such as gender and socio-economic status. Using an estimate of regression model across all six studies, associations between early academic skills, socio-emotional behaviors and later school achievements were defined. The findings indicated strong predictors between early and later reading and math skills, moderate associations for early and later attention skills and statistically
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insignificant correlations for early and late socio-emotional behaviors. With a standardized coefficient average of .34, school entry math skills indicated the most predictive power, followed by reading with an associated coefficient of .17. Patterns emerged between specific math concepts and later math achievement scores, specifically knowledge of numbers cardinality and ordinality were the most powerful predictors. Interestingly, Duncan found a reliable predictor between children who had strong math skills and later became competent readers, he found a weaker relationship between children who had strong reading skills and later developed strong math skills. It seems that strong math skills are a better predictor of higher achievement in general than strong reading skills. Statistically the strongest predictor, according to this project, was the association between early math and later math skills. Attention skill coefficients were weaker, but still statistically significant, indicating a relationship between children's ability to attend to verbal interaction and their ability to grasp math. The associations between early and late socio-emotional behaviors were insignificant indicating early behaviors concerns may not have a direct correlation to academic achievements.

Duncan's analysis also included isolation of gender and socio-economic status (SES) as one of the predictors of academic achievement. To identify a pattern of gender or SES variables a regression analysis was run across all six data sets using first gender then SES as the variable. Gender variable revealed ten of seventy-six indicators with a coefficient of .05 or higher, but the researchers could not find a pattern related to later achievement. The SES interaction coefficients of .05 or greater were found in two of thirty indicators, concluding the SES of children in this study was statistically insufficient as a predictive factor. The findings of Duncan's analysis supported his initial predictions: learning academic concepts during the preschool years affects later school achievement. Early math and reading skills are consistently
associated with higher levels of academic performance in reading and math. Although Duncan's conclusion discounted SES as a predictive factor, there are other studies which refute this perspective and claim the influence of SES is a significant factor. This topic will be addressed later in this paper. The conclusion for the coordinated meta-analysis supported the researchers' predictions that early experiences in math have a lasting affect on later achievement.

Some of the data sets had significant attrition rates which could have biased the data and conclusions and because the data was second hand there was no way to control for collection errors. A significant discrepancy in teachers' credentials was discussed and could discount the generalization of the results across populations. Data called on by Duncan et al. (2007) included ECLS-K data set which consisted of 21,260 children who participated in preschool programs in 1997-98, and were followed through grade three. A second data set, NLSY analyzed second generation children, and focused on 1,756 children born in 1979. It was noted by Duncan, this data is from disproportionate number of children born to young mothers, a population demographic not representative of the general population. The SECCYD, the third data set, collected data on 1,364 healthy newborns recruited from ten hospitals from across the United States. Participants in this study were selected to closely match a national representative sample of ethnic, parental education, family composition and economic variables. The study collected information beginning at infancy and continuing until fourth grade. Data on children's early environments, family members, childcare situations, economic status, and parenting styles was collected. At age three and again at four-years-six-months of age, children were administered assessments for cognitive and language abilities, impulsivity tendencies and social skills. Follow-up assessments were administered in the first, third and fifth grades using the Woodcock and Johnson Test of Achievement.
The fourth date set was the IHDP study, a randomized clinical trail of early intervention program effects on low birth weight babies. The study of 985 infants born before the thirty-seventh week of gestation and weighing less than twenty-five hundred grams at birth, were randomly assigned to a medical only follow-up program or a comprehensive early intervention program, which included a medical component. The infants in the medical model program received clinical visits which monitored their health and development. Infants assigned to the comprehensive program received home visits by a trained team of early childhood interventionists who designed individual programs to promote the premature infants' development. Participants received interventions beginning at hospital discharge through their adjusted age of thirty-six months. At ages three, five and eight, children were given cognitive assessments using the Woodcock & Johnson Test of Achievement and the Wechsler Intelligence Scale for Children. Duncan's fifth data set, MLEPS, included 767 four and five-year-old children who were assessed prior to kindergarten entry on cognitive, socio-environmental indicators, early environments and family variables. Follow up data was collected at the end of kindergarten and the end of third grade. The final data set, The British Birth Cohort study, followed 11,200 infants born in one week in 1970 in Great Britain. Data was collected on early environments, achievement assessments and educational accomplishments as they reached adulthood.

Preschool readiness indicators and later achievement correlations presented by Duncan et al. are strong indicators of the early academic and environmental influences. Influences which children are exposed to in the first five years of life set the trajectory of potential academic achievement for later live (Duncan, 2007).
In a separate study, but consistent with Duncan's findings, Klibanoff (2006) found that preschool math experiences influenced later mathematical achievements. Klibanoff examined the relationship between children's conventional math knowledge and preschool teacher's use of mathematical vocabulary during routine interactions with children. A number of studies have shown strong correlations between adults talking to children and children's vocabulary development; the more complex language a child hears the faster his vocabulary grows (Hart, 1995). Klibanoff hypothesized that if children had more qualitative math input (hearing math words), they would develop more quantitative math knowledge (using math concepts). Other studies have focused on math interventions and direct math teaching and have found positive associations. Still others have focused on the correlations related to socio-economic status of parent's educational levels and math achievements. Klibanoff's research differed because it was designed to understand the effects of math language, which she referred to as "math talk" on children's understanding and use of math concepts. For example instead of saying, "*bring me an extra napkin*", the teacher might say, "*We need to add one napkin to the three napkins we have, because we have four children and we need four napkins.*" Or if the teacher wanted to know if the child understood a concept, she could say something like: *We have three napkins, and four children, how many napkins should we add so every one can have one?*" Klibanoff's theory of embedded math in teacher-child interactions during the daily routine was to determine the extent to which the strategy of indirect but intentional instruction would have on children's math skills during a single year. Would the use of qualitative math language alone produce quantitative math skills over the course of a single year? In other words, can hearing math language teach math skills in a short period of time? Klibanoff sampled 198 children in twenty-six preschool classrooms in the Chicago area selected at random from a pool of volunteers. The sample
included a variety of half day and full day programs, class sizes ranging from fourteen to twenty-five children, as well as socio-economic and culturally diverse programs, all proportionally reflective of national preschool programs (Klibanoff, 2006). Children were given an assessment at the beginning of the year and divided into cohorts based on their knowledge in order to isolate the one year growth indicator. To capture the teacher input, teachers were wired with microphones which recorded adult-child conversations. Teacher input was analyzed through transcription of audiotapes then coded and divided into nine types of interactions considered to be of mathematical relevance. The number of math utterances ranged from a low of 1 to 104 per hour. Because this study was a random sample of schools, teachers and children, Klibanoff chose to use an analytical strategy which is appropriate for nested designs, a hierarchical liner model (HLM) was selected. The study design included a three level HLM, students within the classroom, classrooms within a school and schools within the sample. Three main conclusions were evidenced in Klibanoff’s research. First, there are significant differences in children's math skills by age four which were found to have correlations to family SES. Second, Klibanoff concluded children who experienced more qualitative math, also acquired more quantitative math skills. Third, the amount of math talk had significant associations with the growth of a child's math concept skills over the course of a single year.

Klibanoff’s study supported a theory that preschool experiences improve children's academic achievement in mathematical concepts during the preschool year. In contrast to Duncan's claims, Klibanoff found that math scores for children entering preschool were correlated to socio-economic status (SES) and the amount of growth during preschool remained constant with the SES. However, Klibanoff's research only addressed one year's worth of growth; no indications of how long the increases in math skills were sustained. A second
potential short coming of the math talk research may be the length of the audio samples, lasting one hour and captured twice a year. Because teachers did not know what was being researched, and therefore likely did not alter their interactions, the assumption was made that the two hour sample was representative of the unrecorded classroom time. There was no mention of isolating the out of school influences, such as parent or other family member input nor were the credentials of the teacher isolated. Klibanoff's goal was to examine the in-school effects of teachers' qualitative math input. Klibanoff intends to expand the research to include an experimental study in which preschool children would be assigned to treatment and control groups to determine if there is a relation between math talk and conventional math knowledge. In the meantime, the research indicates positive relationships between embedded math language and children's math knowledge prior to entering kindergarten.

In a third more specific study, Aunola et al. (2004) examined the development trajectories of children as they progressed from preschool to second grade. The purpose of Aunola et al.'s research was to understand the development of children's math skills and label the cognitive experiences related to typically developing mathematical growth. Aunola et al.'s research differs from the two previously discussed projects in that it focused on a broad range of "cognitive antecedents" (p. 699) not specific to math, looking for a set of skills to predict future academic achievement. The study followed children from preschool through second grade which allowed for the cumulative effects of prior knowledge to be evaluated on 194 four and five-year old children in a primary school in Finland. The sample was a homogenous group, which the researcher notes is typical for Finnish schools; however, because of the differences in school structure, children begin school at seven years of age, and attend preschool one year prior. This means the children in this study are chronologically one year older than children in the same
grade in the United States. The study examined two topics: the progression of typically developing children's math skills and the identification of a consistent pattern of indicators which could predict math growth trajectory. Children's math skills were assessed using the Diagnostic Test of Basic Mathematical Concepts six times during the preschool year in five skill areas: counting ability, visual attention, listening comprehension and metacognitive knowledge. First, a simplex model was used to establish the stability of math performance across all six test times. The model findings indicated high stability across all six measurements and a cumulative pattern of growth emerged. A second statistical analysis using a latent growth curve model was used to investigate the association between skills and growth trajectories. As a third analysis, the authors added cognitive variables as covariates to the latent growth curve model. The strongest correlations between early indicators and later math achievements were found in three areas; counting abilities, metacognitive knowledge and listening comprehension. Children's counting ability, and metacognitive knowledge was measured at the beginning of preschool using the Diagnostic Tests for Metacognition and Mathematics, listening comprehension was measured using a Finnish version of the Illinois Test of Psycholinguistic Abilities. Based on the first preschool scores children were place into predicted growth trajectory classes. Math concepts knowledge was measured six times, twice per year from preschool through first grade. Statistical analyses was performed to examine the extent to which the development of mathematical competence was correlated to cognitive antecedents by dividing the results into a two class group, high achievers and low achievers. In one analysis, a growth mixture model was used to define a growth trajectory by dividing the samples into two more classes based on the mean of the slope and level of growth. Two of the antecedent variables, counting (estimates= .56, SE =0.47, p< .01) and visual attention (estimate= 16.28, SE= 7.12, p<.05) had strong predictions for
the rate of growth within both classes. In the final analysis children who scored low on initial math skills assessments showed less improvement over time, indicating the gaps between children with high math skills and those with low math skills gets wider over time without specific interventions. An additional purpose of this study was to define a consistent set of cognitive antecedents which could predict the level and speed of growth of children's math performance. Children with high levels of counting ability showed more and faster growth in math skill development than those who initially did not demonstrate competent counting skills. This indication implies that rote counting is foundational to math future achievement and the ability to grasp rote counting and number sequencing patterns (cardinal and ordinal) allows children to quickly retrieve information and apply knowledge to more complex math computations. The automatic recall of facts appeared to increase the children's ability to progress through math concepts requiring problem solving equations with fewer errors, resulting in more success. Also relevant to the pattern of success was a child's ability to attend to and process verbal information. Children who demonstrated higher abilities to attend to verbal information also demonstrated higher math skills.

As with the previously discussed research projects, Aunola et al.'s (2004) research indicates acquisition of math skills in preschool provides children with higher school entry skills which are carried into later school. Unlike Duncan et al.'s research but consistent with Klibanoff et al., Aunola et al. found correlations related to gender. The researchers noted that among the highest achieving students, the rate of growth between boys and girls was significant, and boys' rate of growth was faster than girls in mathematical concepts.

However, consistent with the other two studies, Aunola et al.'s research supported the claim that all children who acquire informal math skills prior to the introduction of formal math
sustain higher levels of math achievement through-out elementary school. Additional data in this study also related metacognitive skills (attention span, listening and pro-social behaviors) to math achievement.

It must be noted Aunola et al.'s study was carried out exclusively on children in Finland; thus, the chronological age dynamics of language, specifically syntax, may preclude the results being generalized to other populations.

In each of the three research projects discussed, focusing on the extent preschool math instruction effects later math achievement there emerges two important messages, first children are capable of understanding and using complex math, and secondly young children in every setting should experience effective research-based curricula and teaching practices which build on children's natural inquisitiveness. Children use and enjoy math during every day play, math embedded in preschool settings offer opportunities to deepen children's conceptual understanding of mathematics. Based on the constructivist perspective, children's attitudes and aptitudes for future mathematics can be fundamentally shaped during the preschool years. It is likely that young children's positive experiences with math can contribute to future math achievements.
Chapter III- Results and Analysis Relative to Problem

In the area of early childhood education for three to five-year-old children, there are four primary curriculum models which are most commonly used in the United States: High/Scope, Creative Curriculum, Montessori and Reggio Emilia. All four models use a child-centered approach focusing on environmental arrangement and classroom materials to elicit children's independence, advance their social relationships and embed learning concepts into daily routines. Within each model, teaching and evaluating mathematics is a secondary element, the same is true for science (National Association, 2008). On the other hand, emergent literacy has received a lot of attention, both in teacher preparation programs and in the preschool curriculum, likely because reading has been highly researched and is viewed as the lynch pin in academic success (Trelease, 1979/2001).

The area of emergent mathematics is still in its infancy stages as far as research goes, but preliminary results are promising for effects which may result from attention to children's natural inquisitiveness for informal mathematics and the lasting results. A common conclusion from Duncan, (2007) Aunola, (2004) and Klibanoff (2006) was that mathematic knowledge is cumulative, which may indicate that teaching early math is likely to elicit later math achievements. Paying more attention to children's use of informal mathematics and facilitating the transition from informal to formal mathematics may benefit children as much as early literacy, something not previously supported by early childhood pedagogy.

The notion that math skills acquired prior to kindergarten entry are sustained and even grow at a proportionate rate through elementary school is a common conclusion which emerged each of the research projects reviewed. Duncan et al.'s (2007) and Aunola et al.'s (2004) research
may have pedagogical implications which indicate the need to look for correlations between teachers' training, attitudes, and aptitudes and children's sustained math skills. Researchers identified two indicators common in children as they entered kindergarten and later demonstrated high levels of math competencies. The indicators with the strongest coefficients were rote counting and attention skills (Aunola, 2004; Duncan, 2007; Klibanoff, 2006). An additional finding common in all the previously cited research indicated a moderate correlation between the ability to follow verbal interactions and quickly grasping mathematical concepts.

Children's natural attraction to mathematics does not mean that we can leave early math to chance and assume that children are getting what they need from the environment. Children's cognitive abilities increase as adults systematically scaffold experiences (Baroody, 2000; Epstein, 2009). Researchers have confirmed early math experiences fundamentally shape learning potential. It is clear from the research that children are capable mathematicians; the key is to neither under estimate nor over estimate the value of early intervention for math achievement. Researchers have identified the influence of preschool math, but have yet to agree on specific content or instructional strategies.
Chapter IV- Recommendations and Conclusions

Research tells us that early mathematics is a strong predictor of later achievement (Ginsburg, Lee, & Boyd, 2008). Children have the potential and natural desire to learn and use mathematical concepts. Leading professional organizations, National Association for the Education of Young Children and the National Council of Teachers of Mathematics recommend an increase in mathematics instruction for pre-kindergarten children (National Association, 2008; National Council of, 2001). Although past early childhood education practices have cast doubt on children's ability to grasp abstract concepts, new research is revealing that even very young children can learn, retain and use rather complex concepts (Johnston, 2009).

Acquiring math language may be one of the cognitive antecedents necessary for successful and sustainable early math (Klibanoff, 2006). Increasing children's exposure to and use of math language may provide the foundation from which more formal math skills can be built. If research continues to produce more evidence that demonstrates even modest improvements in children's math knowledge when math language is infused into daily adult-child interactions, the field of early childhood could provide children with increased potential for math achievements. Training teachers to use more "math talk" will not require a curriculum overhaul of the four most commonly used curriculum programs, a refocusing of the teacher's observations and increased pre-service education. Early childhood leaders, rethinking the approach to the preparation of teachers, can include course work that teaches the psychology of children's mathematical knowledge (Ginsburg, 2007). Ginsburg et al. described the essentials of teacher preparation course work to include a comprehensive developmental approach that promotes the synthesis of child development, mathematical concepts and teaching pedagogy.
In rethinking preschool curriculum, in the absence of a math based curriculum, educators can modify current classroom materials and adult-child interactions to focus on mathematics. The National Council of Teachers of Mathematics with support from the National Association for the Education of Young Children has published a set of guiding principles for teaching mathematics. The paper, titled *Principles and Standards for School Mathematics (PSSM)* includes prekindergarten through second grade recommendations. The long-standing curriculum models, Montessori, High/Scope, Creative Curriculum and Reggio Emilia, are grounded in a child-centered, active learning framework and the NAEYC guidelines are closely aligned. The *PSSM*, as written, dove tails seamlessly with NAEYC recommendations of developmentally appropriate practices therefore could be integrated into existing curriculum frameworks.

There are a few noted barriers and challenges for increasing the attention paid to preschool mathematics. First and foremost, even though long standing research indicates that high quality preschool is good for children, the definition of high quality has a wide range of acceptable practices. While states are increasing funds available to preschool programs for at-risk children, the majorities of programs across the United States are still privatized and require parents to pay tuition. Even within the state funded programs, there is a significant variation in the investment each state makes and the standards of quality identified by each state. Access to high quality preschool programs is most often afforded to upper income families, leaving lower SES families with more affordable but often lower quality preschools (Johnston, 1998). Increasing math competencies for children in higher SES families may result in amplifying the gap between children who have prior knowledge and those who do not. A second possible result from improved mathematics in preschool could be an increase in those who exploit the research findings and advocate for developmentally inappropriate direct instruction of mathematics.
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concepts. There is a fine line between developmentally appropriate, child-centered instruction which builds on children's knowledge and interest and teacher directed skill drill instruction.

To be successful with children's potential, we must first teach the teachers. Many teachers and prospective teachers of preschool children are poorly prepared to teach mathematics (Ginsburg, Lee, & Boyd, 2008). "At the college level, courses in teaching early childhood mathematics are rare" (Ginsburg, 2007 p 41). As a result, preschool math gets relegated to a secondary level of importance and teachers do not intentionally plan or instruct mathematics. Improving the teacher preparation programs needs be a priority if we want to see changes in instructional quality. As essential as learning math is, it will only benefit children if the teachers can bring it to life with appropriate experiences in the preschool setting. An effective preparation program will need to weave together mathematical content, pedagogy and knowledge of child development to help children develop an effective mathematical perspective. University programs in collaboration with researchers can create a change in teacher standards.

In order to advance the understanding and investment in preschool mathematics, more quantitative research is needed. An investigation into the specific mathematical content which produces lasting effects is yet to be completed. For example, the Building Blocks project funded by the National Science foundation (Sarama, 2004) found that "mathematical literacy" not "numeracy" was the most important focus of early mathematics, however the data put forth was mostly qualitative. In order to figure out exactly what concepts children need to have for a good mathematical beginning, more critical inquiry will be needed.

While it is necessary to synthesize the research and discover a common theme or finding, the usefulness of such an exercise seems inconsequential for this topic because of the variety of approaches to the research. The research is really not very well developed, not replicated and
certainly not conclusive. The diversity of the research methodologies, settings and assessment approaches leads only to conclude that early experiences shape who we become and how we approach learning. Characteristics of effective preschool mathematics curricula are not clearly identifiable, there is agreement that early math can play a critical role in future math but the amount and type of mathematical instruction is undetermined.

Further research in the areas of teacher preparation and mathematics course work as well as longitudinal studies on child outcomes is necessary. A research project designed to study three variables, teacher preparation programs, influences of in-service training and ongoing assessment of children's math knowledge could offer additional information for early childhood leaders, policy makers and funders. Three groups of children representative of national demographics could be divided assigned to study groups. One third would be assigned to programs in which teachers participated in a teacher preparation program in which math is a required component, one third assigned to a program in which teachers are provided in-service training on the math standards recommendations by NAEYC and NCTM as well as instructional strategies, the last third would be assigned to programs in which teachers had neither preparation course work nor in-service training. Children's math knowledge would be assessed using the Woodcock Johnson assessments prior to participation in preschool, at the end of preschool and annually from kindergarten through second grade. Children would be assigned to similar cohort groups based on variables of SES, initial assessment scores and gender. Children would be assigned so that each program had an equal distribution of cohort groups. Researchers would study the teachers' instruction at prescribed intervals via a direct observation checklist to identify any common patterns of teaching strategies. Data collected would be analyzed for effective outcomes in children's scores on each of the annual assessments. Comparison of the data from
the three groups of scores may reveal the extent to which teacher preparation effects math
knowledge. A second level of analysis could be a comparison of teachers' strategies among
those teachers whose children's scores showed positive gains to determine if there are common
instructional strategies which may lead to effective outcomes for children. Instructional strategy
variables could include the type, frequency and duration of math interactions and the
environmental resources available to children and teachers.
References


