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Instructional Interactions that Influence Children's Mathematical Development  
in a Sample of Head Start Classrooms

by

Melissa Dianne Perkins

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Education

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of the

University of California, Berkeley

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## Abstract

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in a Sample of Head Start Classrooms

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Melissa Dianne Perkins

Doctor of Philosophy in Education

University of California, Berkeley

Professor Susan Holloway, Chair

This study evaluated the influence of general and mathematics-specific classroom instructional quality on the mathematical development of a sample of Head Start preschool children. It also examined whether children's age, pre-test mathematical knowledge, and English language learner status influenced the quality of their curricular experiences and subsequent mathematical development. Findings indicate that mathematics-specific measures of quality, specifically curriculum intensity, significantly influenced children's mathematical gains, while broader measures of instructional quality, as measured by general cognitive support, did not significantly predict mathematical development. The quality of mathematical instruction and children's mathematical development were also found to be unrelated to general instructional quality or overall classroom quality. Results also indicate that children who entered preschool with more mathematical knowledge experienced more intense curricular experiences. Finally, the influence of ELL status was significant, with Asian-American ELL children experiencing greater curriculum intensity and making greater mathematical gains from pre-test to post-test than both their ELL and predominantly English speaking peers. This study reaffirms the importance of curricular intensity in preschool mathematics instruction. It also provides preliminary evidence suggesting that teachers' mathematical instruction may be a distinct early childhood content area, which does not necessarily relate to the overall quality of the classroom or to teachers' general instructional quality. Implications include more planned mathematical instruction in early education settings, the inclusion of formative assessments in early childhood curriculum packages, improvements to teacher training programs in preschool mathematics, and ongoing professional development to ensure that early childhood educators continually make improvements to the mathematical quality of their instruction.

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## CHAPTER 1. INTRODUCTION

Research on American children's mathematical development exposes a pressing need for greater mathematical support within our nation's schools. Cross-nationally, the mathematical achievement of American students lags significantly behind that of Asian children, and such performance discrepancies are present as early as first grade (Stigler, Lee, & Stevenson, 1990). One explanation for the superior mathematical performance of Asian children is their greater mathematical preparedness in early childhood. Asian children tend to begin formal schooling with a stronger knowledge of counting, arithmetic, and concepts of more and less (Ginsburg, Choi, Lopez, Netley, & Chao-Yuan, 1997).

While cross-national studies reveal our nation's relative position in mathematical achievement globally, reports of national averages mask a persistent socioeconomic achievement gap within our country. Differences in children's mathematical knowledge exist across socioeconomic status as early as three years of age (Ginsburg, Klein, & Starkey, 1998). Children from low-income backgrounds have fewer educational experiences at home and often go on to enroll in lower quality schools (Baroody, Lai, & Mix, 2006). As compared to their middle-income peers, American children living in poverty begin formal schooling at a significant disadvantage, and this achievement gap persists throughout elementary school (Downer & Pianta, 2006; Entwisle & Alexander, 1992) and into adolescence (Schoon et al., 2002), ultimately compromising opportunities for college entry and access to many high-paying professions. The long-term outcomes of early disadvantage can be devastating: lower mathematical skills, lower earned wages, and lack of employment mobility (Ball, Hill, & Bass, 2005; Geary, 2000).

Although the number of American children living in poverty steadily declined in the 1990s, recent data indicate that child poverty is again on the rise, with the number of children under the age of 6 who are poor increasing by 24% between 2000 and 2007 (National Center for Children in Poverty, 2008). Addressing the cognitive development needs of these disadvantaged children is a pressing societal need.

In an attempt to ameliorate the negative influences of low-income on children's developmental outcomes, particularly their language, literacy and mathematical achievement, many public dollars are devoted to funding early educational programs. These compensatory education programs aim to enhance children's preparedness for school by supporting physical, emotional, and educational well-being. Model programs, including Head Start (McKey et al., 1985), the Carolina Abecedarian Project (Campbell & Ramey, 1994), and the Perry Preschool Project (Schweinhart, 2004), have documented positive and, sometimes, long-term outcomes for children enrolled in high quality center-based programs. Although these programs are not reflective of the typical preschool experiences of low-income children (Phillips, Voran, Kisker, Howes, & Whitebook, 1994), this area of research reinforces the importance of providing high quality preschools for children whose early experiences might otherwise lack the enrichment and support necessary for healthy cognitive development.

Perhaps as a result of these model initiatives, preschools are increasingly looked to as centers of academic preparation and instruction (Zigler, 1987). High quality preschools are associated with low-income children's cognitive growth (Loeb, Fuller, Kagan, & Carrol, 2004; Peisner-Feinberg et al., 2001) and are an essential component of their early experiences. While language and literacy development has long been considered an important goal of preschool participation, only within the past decade has mathematical development been recognized as an important aspect of children's school readiness.



Beginning in the 1980s, researchers began to uncover young children's mathematical competencies, some of which are demonstrated in newborns (e.g., Fuson, 1988; Starkey, 1992). As infants, children possess sensitivities to differences in numeric quantities (e.g., Cooper, 1984; Wynn, 1998). Then, as they age, children learn about mathematics in the context of everyday activities, including shopping trips, conversations about birthdays and numbers of presents, rides in elevators, and observations of Sesame Street's Count expressing his love for counting sets of objects (Gelman and Massey, 1987). What results is an early mathematical understanding that involves basic skills and rote memory, as well as advanced thinking processes. The emergent mathematical competencies include knowledge about number and operations, shape, space, measurement, and pattern. Whereas young children were once thought to lack mathematical knowledge (Piaget & Szeminska, 1952), research now indicates that they demonstrate a broad and, sometimes, complex understanding of mathematics.

As developmental researchers continue to identify and describe young children's competencies, practitioners and educational researchers have begun to utilize existing research for improving early mathematics education. Although children naturally observe mathematics in their daily environments, adult support is necessary to help children clarify, deepen, and extend their mathematical concepts, transforming everyday understandings to rule-based, scientific knowledge (Vygotsky, 1986). Research has revealed that the frequency of parents' number-related activities at home has been found to correlate with preschool children's mathematical achievement (Blevins-Knabe & Musun-Miller, 1996) and enrollment in higher quality child care has been found to predict children's long-term mathematical achievement (Peisner-Feinberg et al., 2001).

Despite its importance, mathematics exists minimally and receives little support in typical preschool classrooms (Ginsburg, Lee, & Boyd, 2008). Traditionally, literacy, rather than numeracy, has been the instructional focus of early childhood educators (Baroody et al., 2006), and preschool teachers often feel that "young children shouldn't do mathematics" (Copley 2004, p. 403). This antipathy towards mathematics for young children may be explained by two concerns: (1) the fear that preschool education, long embraced as a time of child-directed exploration and discovery, may become rigid and didactic with the inclusion of "academic" skills and (2) preschool teachers' feelings of unpreparedness to understand and support young children's mathematical development.

Researchers must do more to provide practical information that early educators can use to guide their classroom practices. Although literature now exists to describe children's early mathematical competencies and curricular activities have been developed for teachers' use, researchers are yet to identify specific instructional techniques that are associated with preschool children's mathematical development. For example, there is little research to suggest whether children's mathematical competencies are developed adequately through the use of skill-building mathematical activities, or whether additional cognitive supports, such as those that develop higher order thinking skills, are also necessary. Such gaps in our knowledge suggest that research is needed on the teaching process, a relatively unexplored topic within the literature on mathematics for young children (Ginsburg et al., 2008). Just as has been done for language and literacy, researchers must now determine the specific instructional features that comprise a preschool classroom high in mathematical quality.

Preschool quality has been measured and described in multiple ways, the most common of which include global quality, structural quality, and process quality. Global quality refers to broad assessments of overall classroom quality (e.g., physical environment and safety), structural

quality gauges survey-type quantitative features (e.g., ratios, group size, teacher education), and process quality measures specific qualitative classroom and instructional features (e.g., interactions and curricula) (Phillips et al., 1994). Research indicates that process features of classroom quality predict children's developmental outcomes better than structural or global measures (Howes et al., 2008). Process quality, however, assesses a wide range of classroom features, including teacher-child interactions, curriculum implementation, and the use of learning materials, and each of these features may uniquely influence children's development. To identify optimal strategies for instruction in early mathematics, this study evaluates the effects of two distinct measures of classroom process quality on children's mathematical development: general cognitive practices and specific instruction in mathematics.

Although both general cognitive practices and specific instruction in mathematics assess the quality of teachers' instructional interactions, they capture very different classroom processes. General cognitive practices may reflect teachers' pedagogical orientations toward supporting children's overall cognitive development, while specific instruction in mathematics may reflect teachers' abilities and efforts to enhance the specific cognitive skill of mathematics. Furthermore, teachers may demonstrate different patterns of strength across these instructional practices: high on both, low on both, or high on one and low on the other. Because children's mathematical fluency may depend upon general thinking skills, such as analysis and interpretation, as well as specific mathematical skills and knowledge (Resnick, 1989), this study closely examines the relationship between these features of classroom instructional quality and children's mathematical development. As such, this study investigates how the skills necessary for mathematical development is influenced by specific instruction in mathematics and more general cognitive capacities for thinking. It will also determine how the effects of mathematics curricula are influenced by teachers' general support for cognitive development.

The objectives of this study are (a) to investigate the relationship among general classroom quality, general cognitive instructional quality and mathematics-specific instructional quality in a sample of Head Start classrooms, (b) to understand the relations of general cognitive practices and specific instruction in mathematics to children's mathematical development, (c) to understand how these two distinct instructional interactions may work together to influence children's mathematical development, and (d) to understand the influence of children's age, language status, and pre-existing mathematical knowledge on children's experiences of curriculum intensity and mathematical development. These findings will inform teaching strategies and curricula that promote children's mathematical school readiness. Specifically, they will suggest whether specific instruction in mathematics is sufficient to promote young children's mathematical development, or whether its influence is strengthened through teachers' general cognitive support practices. They will also provide insights into the ways in which children's background characteristics relate to instructional patterns and mathematical development.

Five research questions were used to explore the relationship between teachers' instructional practices and children's mathematical development:

1. To what extent are general classroom quality, general cognitive practices, and specific instruction in mathematics related to each other?
2. Controlling for general classroom quality, do general cognitive practices and specific instruction in mathematics predict children's mathematical development?

3. What is the independent contribution of specific instruction in mathematics after general cognitive practices have been taken into account?
4. Do general cognitive practices moderate the effect of specific instruction in mathematics on children's mathematics development?
5. What is the influence of children's age, existing mathematical knowledge, and English language learner status on children's curricular experiences and mathematical development?

Given the recent push toward increasing mathematics instruction in preschool (National Association for the Education of Young Children [NAEYC] & National Council of Teachers of Mathematics [NCTM], 2002; NCTM, 2000), determining the effects of classroom instructional practices on children's mathematical development is especially timely. Today's mathematics curricula and professional development programs aim to synthesize the growing research literature and respond with practical information and educational materials for practitioners, yet continued research is necessary to improve these efforts, particularly in regard to specific recommendations for teaching.

The study of effective instructional practices is also important for ongoing developmental research, since much remains to be understood about children's mathematical knowledge and the ways in which it develops. By determining how the quality of specific instruction in mathematics and general cognitive support for thinking skills influence young children's mathematical development, educational researchers may spark new developmental research questions about the cognitive capacities underlying mathematical development.

## CHAPTER 2. REVIEW OF THE LITERATURE

This chapter will review the literature on early mathematical development with a focus on the ways in which preschool experiences and teachers' instructional techniques facilitate children's mathematical learning. The first section presents the theoretical framework used to guide the study. Next, research on the development of young children's mathematical competencies and early childhood educators' role in instruction is reviewed. The final section presents the research on instructional practices that influence learning and development, including concept development, quality of feedback, language modeling, and specific instruction in mathematics. In its entirety, this chapter describes both the rationale and the need for investigating the relationship between teachers' instructional practices and children's mathematical development across the preschool year.

### Theoretical Framework

The literature on early mathematical development and Vygotskian theory about the social nature of learning provide the conceptual framework for this study. Vygotsky's work is essential for understanding the influence of instruction on children's developing mathematical knowledge. When children receive support for learning from an adult or peer, their knowledge advances beyond their informal, intuitive understandings and into the more formal concepts, procedures, and symbols of academic mathematics. Vygotsky understood this transition of knowledge as moving from children's "everyday knowledge" toward rule-based "scientific" knowledge (Vygotsky, 1986).

Young children are capable of experiencing and learning about mathematics through everyday activities and interactions. Mathematical learning can occur in the context of activities in which mathematics is the main goal or in which it is embedded within an alternate learning agenda (e.g., art or cooking activities). Important components of mathematical interactions for young children are manipulatives and the involvement of an adult or more competent peer. As mathematical activity partners, teachers are essential agents in this social learning process; they clarify, deepen, and extend children's burgeoning knowledge of mathematical skills and concepts.

Vygotsky's (1962, 1978) conceptualization of the social nature of development highlights the importance that social interactions have on facilitating learning. Children learn about mathematics and numbers in the context of social interactions with more capable partners, and, throughout the learning process, gradually internalize the concepts and develop the competencies to understand and independently apply the knowledge. Vygotsky identified the zone of proximal development (ZPD) and the accompanying support provided by the more competent partner as key components of this process. The ZPD is the difference between a child's current level of ability and his ability level with guidance and support. The more competent partner provides a minimal, yet sufficient, degree of assistance to enable the child to exhibit task competence, and, as independent competencies develop, carefully reduces the support to keep the child in the developmental zone. This type of support is commonly referred to as scaffolding (Wood, Bruner, & Ross, 1976). When learning is mediated by social interactions, a child internalizes the ZPD activities and development occurs; the child can do alone that which previously required support. Competent partners, especially parents and preschool teachers, are essential agents in young children's learning processes.

Vygotsky's work has been both the subject of educational research (Benigno & Ellis, 2004; Saxe, Guberman, & Gearhart, 1987; Wood et al., 1976), as well as the source of practical information guiding teachers' general cognitive practices with children. The social nature of

learning, as well as the importance of teachers' roles in guiding children's development, informs both the study's design and research questions.

#### Early Mathematical Competencies

Cognitive research on young children's mathematical competencies is relatively new in comparison to that pertaining to language and literacy development. Seminal works in the 1980s and 1990s revealed that young children develop everyday mathematical competencies and demonstrate the ability to learn many more mathematical concepts than previously assumed. These concepts include number and operations, shape, space, measurement, and pattern, and they involve basic skills, rote memory, and advanced thinking processes. As developmental researchers continue to explore children's mathematical understandings, educational researchers and practitioners have begun to apply these research findings to classroom practices.

Contrary to Piaget's notion that teaching number concepts to young children would be fruitless (Piaget & Szeminska, 1952), within the past decade, mathematics has become an important focal point in the field of early childhood education. Piaget's theory of strict cognitive developmental stages is a major contributor to the field's underestimation of young children's mathematical abilities and for the relative absence of early mathematics education. Piaget (1954) held that although children are born with basic perceptual and learning abilities that allow them to construct number concepts, they are unable to functionally use number (e.g., counting) until age 7, during the period of concrete operations. Piaget understood early counting to be a rote activity, which only becomes truly numeric and conceptually meaningful, when it can be used functionally, as demonstrated by success in a number conservation task. Even then, however, children's numeric understanding is dependent upon the presence of concrete objects and the ability to visually observe the correspondence between sets. According to Piaget, children are only capable of appreciating the correspondence of objects and the numerals (non-objects) used to count them during the period of formal operations, which begins at age 11. In line with this perspective, the cognitive structures underlying numeric abilities were not believed to emerge until children are in elementary school. Hence, mathematical instruction in preschool was thought to be meaningless because young children supposedly lacked the cognitive capacities to think or act numerically.

While Piaget's theory has had a profound impact on subsequent cognitive theories, modern researchers contend that there are many mathematical developments that precede those revealed by Piaget's methods. It has been argued that Piaget's use of non-standardized interviews and highly-verbal questioning techniques masked many of young children's mathematical competencies (Ginsburg & Opper, 1988). Ginsburg and Opper (1988) also point out that, even Piaget, himself, later reconsidered the notion that mental structures underlie all cognitive abilities and that these emerge in a strict stage-like manner.

Today, in response to a growing literature that reveals young children's many mathematical capabilities, there is greater emphasis on mathematical development and instruction in preschool. Once considered fruitless, "too academic" and developmentally-inappropriate for young children, mathematics is now accepted as an integral component of high-quality early childhood programs (American Educational Research Association [AERA], 2005).

In fact, mathematical instruction occurs in many classroom settings: children's play, curricular activities, and teachers' own deliberate and planned instruction, and both the National Council of Teachers of Mathematics (NCTM, 2000) and the National Association for the Education of Young Children (NAEYC, 2005) have adopted mathematical standards for pre-kindergarteners (Neuman & Roskos, 2005). Cognitive research has revealed that young children

demonstrate many mathematical competencies, even prior to the onset of verbal counting. Soon after birth, infants demonstrate quantitative abilities, such as a sensitivity to differences in one-, two- and three-quantities (Wynn, 1998). Infants have also been observed to have subitizing abilities (Kaufman, Lord, Reese, & Volkman, 1949), a rapid process which enables them to enumerate small set sizes (Ginsburg et al., 1998), and 12- and 18-month-olds have been found to observe numerical patterns between sets of objects (Cooper, 1984). Older infants have also been observed to correctly determine the sums and remainders of small-set non-verbal addition and subtraction problems (Starkey, 1992). Three- and 4-year-olds may know the number series and count small sets of objects (Fuson, 1988), as well as verbally count up to 30, copy patterns, and name simple shapes (Klein, Starkey, & Wakeley, 1998). By kindergarten, children possess a wide array of mathematical competencies (Ginsburg et al., 1998), including an understanding of complex concepts such as “half” and “zero” (Bialystock & Codd, 2000).

Prior to the formal instruction of elementary school classrooms, young children experience mathematics in their natural environments and develop mathematical ideas of their own. This everyday mathematics includes understandings across five mathematical domains: Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability (NCTM, 2000). Everyday mathematics develops through children’s daily interactions in ordinary environments, usually in the absence of direct instruction from adults (Ginsburg et al., 2008). It is an essential and an inevitable feature of cognitive development. For example, children may experience the adding or subtracting of numbers through their play at a “grocery store” register or may explore shapes and measurement through block play. Or, children may experience algebra through their exploration of patterns and may begin to analyze data by sorting objects by color or size.

Although children independently develop an everyday understanding of mathematics, intentional adult instruction is necessary to clarify and deepen their burgeoning mathematical knowledge, as well as to correct any developing misconceptions. Young children demonstrate both remarkable competence, as well as interesting incompetence about mathematical ideas (Ginsburg et al., 2008). For example, although young children can spontaneously develop advanced counting strategies for determining a sum (e.g., given 8 and 3, a child counts on from the larger number, “eight... nine, ten, eleven”) (Baroody & Wilkins, 1999), they often fail to recognize that the familiar equilateral triangle is not the only version of the shape; non-standard triangles, such as elongated, skinny or right-angled triangles are triangles, too (Clements, 1999). Teacher support is necessary in order to transform children’s everyday mathematical understandings to the rule-based, scientific ones developed through direct instruction. However, while many academics and policy makers have embraced the notion of preschool mathematics, the early childhood teaching community has been slower to make the transition. Typically, early childhood educators are unprepared to teach mathematics. They often express discomfort with the subject, devalue its importance, and either teach it poorly or avoid it altogether (Ginsburg et al., 2008). This is not surprising, however, considering that teachers often know very little about what preschool math “looks like” or how to support it in their classrooms. Educational researchers must do more to stress the importance of early childhood mathematics and support teachers in understanding their role in early mathematics education.

#### The Role of the Preschool Teacher

Ginsburg et al. (2008) have identified six components of an early childhood mathematics education that supports both mathematical content and thinking skills. These include a rich physical environment, exploration and engagement in activity through play, adult guidance in

teachable moments, teacher initiated projects and guided explorations of complex topics, a mathematics curriculum, and deliberate and planned instruction. Whether they are providing direct instruction or creating engaging opportunities for rich interaction among children, knowledgeable early childhood educators are the keys to success across all six educational components. Teachers are essential for guiding activities toward learning goals, cultivating higher order thinking skills, focusing children's attention on the relevant mathematical ideas, correcting misinformation, and transforming children's everyday mathematical knowledge into theoretical, scientific concepts.

Although the field has identified mathematical domains and learning goals for young children (NAEYC, 2005; NAEYC & NCTM, 2002; NCTM, 2000), specific models for the development of children's mathematical thinking and for the sequence of instruction have yet to be defined (Pianta, 2008). There is also no certainty as to whether a single cognitive capacity underlies general mathematical development or if unique capacities are required for knowledge across mathematical domains. These gaps in understanding are likely due to the relative infancy of cognitive studies in early mathematical development. Yet, they pose important challenges for the educational community, who must develop and evaluate curricula for teaching and supporting the skills and concepts about which scientists are still learning.

Early mathematics curricula are developed based on researchers' best understandings of young children's mathematical learning trajectories, including information about the breadth of children's mathematical knowledge, the order in which they demonstrate competence in mathematical tasks, and the instructional sequences required to support specific mathematical goals (Clements & Sarama, 2004). Despite this increased emphasis on preschool mathematical instruction, evaluations of effective instructional practices in early mathematics are scant. One reason why little research exists on teaching mathematics to young children is because it is so atypical and infrequent an event in everyday preschool settings (Layzer, Goodson, & Moss, 1993; Lee & Ginsburg, 2007a). Studies of teacher practices reveal that preschool teachers often express concern over their ability to support mathematics in their classrooms and many narrowly conceptualize mathematics as limited to numbers and shapes (Copley, 2004; Farran, Silveri, & Culp, 1991). This is not surprising, however, considering the insufficient preparation provided by early educators' training curricula. Reviews of teacher preparation programs reveal multiple literacy course offerings, but as few as one course in general, not preschool, mathematics (Copley, 2004; Ginsburg et al., 2005). Thus, despite the abundance of academic research on young children's mathematical capabilities, practical information for early childhood educators is lacking and teachers are still underprepared to support mathematics and implement mathematical curricula in their classrooms (Copley & Padron, 1999). Teachers' uncertainty and lack of confidence in mathematics is illustrated by one teacher's reflection upon her participation in a study of mathematics pedagogy.

Overall I'm feeling, I don't know much about teaching math. I know a little bit, you know, enough that, I know which materials to provide the children. But I really, you know, there are a lot of uh... This has made me think a lot about different aspects of teaching math that I haven't really thought of before in preschool. (Lee & Ginsburg, 2007a, p. 134)

Although the field has not yet identified or recommended the instructional strategies best suited for supporting young children's mathematical development, general findings from studies on instruction and learning provide an informed starting point. An instructional combination of mathematics-specific support, such as research-based mathematical activities, as well as general

cognitive supports, such as concept scaffolding and language-rich environments (DeBaryshe & Gorecki, 2005), are logical points of origin for identifying the teaching techniques that maximally support children's mathematical development. The effectiveness of these instructional strategies requires further study, however.

In sum, despite the advances in our understandings of children's mathematical competencies, research on early mathematics is still needed "on several relatively unexplored topics – research on what children can do in rich environments, on teachers' knowledge and how to enrich it, and on teaching itself" (Ginsburg et al., 2008, p. 15). Specifically, Pianta (2008) argues that "we need more careful study of effective instructional processes...and how to improve them" (p. 12). In response to that research agenda, this study explores the influence of teachers' instructional practices on children's mathematical development during the preschool year. Once particular instructional practices are determined to be significantly related to children's mathematical development, educational researchers can recommend to early childhood educators the specific teaching strategies that create high quality mathematical learning environments.

#### Dimensions of Classroom Quality

High quality mathematical learning environments for young children first require high quality preschool experiences. High quality preschools and well-trained teachers are recognized as essential for preparing young children for entry into formal schooling. Children who attend high quality preschool programs exhibit higher levels of verbal and numerical achievement, cope better with school tasks, and receive higher ratings of social skills than do children attending lower quality programs (Burchinal, Lee, & Ramey, 1998; Campbell & Ramey, 1994; Peisner-Feinberg et al., 1999). Typically, ratings of classroom quality focus on features of the physical environment, such as materials, play spaces, and safety, and on broad categories of classroom processes, such as interactions and activities (La Paro, Pianta, & Stuhlman, 2004). Specific classroom processes, including general cognitive practices and curricular experiences, are also important aspects of classroom quality, and have been found to be better predictors of children's developmental outcomes than structural measures alone (Howes et al., 2008).

One of the most widely used classroom assessment instruments is the Early Childhood Environment Rating Scale (ECERS), a standard measure of global classroom quality that broadly assesses the structural, physical, and process features of childcare programs (Harms & Clifford, 1980; Harms, Clifford, & Cryer, 1998). The primary foci of the ECERS, however, are the physical environment and classroom safety. The ECERS includes 37 rating items in the areas of personal care routines, space and furnishings, language-reasoning experiences, activities, interactions, and adult needs. High ratings on the ECERS have been associated with advantages in children's language and academic skills (Peisner-Feinberg et al., 2001; Loeb et al., 2004).

Although, in theory, classrooms that rate highly on global measures of classroom quality should provide the necessary structure to enable higher quality teacher-child interactions, this is not necessarily the case. Global measures of quality, such as the ECERS, often lack observations of specific classroom activities, general cognitive practices, and information about curricula use (Loeb et al., 2004), and classrooms have been found to rate highly on global evaluation measures, yet have rated low on actual observations of mathematical instruction and support (Frede, Jung, Barnett, Lamy, & Figueras, 2007). This suggests that the quality of teachers' instructional support must be evaluated independently from general classroom quality, which is limited primarily to health and safety, materials, and survey measures of program features, such as teacher child ratios.



Because mathematical mastery and fluency may be dependent upon general habits of mind, including inquiry and interpretation, as well as a domain-specific set of skills and knowledge (Resnick, 1989), this study focuses on two instructional strategies that likely support mathematical development: general cognitive practices and specific instruction in mathematics. General cognitive practices provide support for general cognitive development and higher order thinking skills, while specific instruction in mathematics specifically supports the development of mathematical knowledge and skills.

#### General Cognitive Practices

Throughout the course of a day, preschool teachers have countless opportunities to scaffold and support young children's learning. Through both child- and teacher-initiated activities, children learn when they are challenged and supported to do what they could not do before. A teacher's ability to scaffold a child's activity influences the degree to which the child independently masters a task or concept and learns to think critically to solve problems. Therefore, particularly relevant to studies of children's intellectual achievement are evaluations of instructional teacher-child interactions. I will briefly review three interactional constructs that support children's general cognitive development and thinking skills: concept development, quality of feedback, and language modeling. Although these are not the only instructional interactions that support general cognitive development, they are the focus of this study due to their relevance across learning domains and their ability to be measured using reliable and valid research instruments.

#### Concept Development

Concepts are thinking tools used to extend one's existing knowledge to novel situations and to develop theories for understanding the world. Three to five-year olds have demonstrated conceptual reasoning about obvious and non-obvious entities, including germs, body organs, and human thought (Gelman, 1998).

In the classroom, concept development refers to "the degree to which teachers promote higher order thinking and problem solving, going beyond fact and recall discussions with children" (La Paro et al., 2004, p. 414). This construct does not necessarily reflect the development of specific concepts (e.g., weather or adding), but captures teachers' use of instructional strategies that encourage understanding and thinking skills, rather than promote rote learning. Teachers who engage extensively in concept development consistently and intentionally encourage children's use of analysis, interpretation, evaluation, and problem solving (Pianta, La Paro, & Hamre, 2006), thereby enabling them to develop the skills to think critically, think creatively, and make decisions. These are general thinking skills independent of instructional content (Underbakke, Borg, & Peterson, 1993). Children not only learn about the immediately relevant ideas, but also develop the habits of mind necessary to apply that knowledge to novel situations. When students are supported in learning to think more effectively, they develop more efficient ways of processing subsequent information.

Preschool teachers can engage in concept development by creating classroom experiences that include hypothesizing and testing, assessing arguments, solving interpersonal problems, and probabilistic thinking (Underbakke et al., 1993). They can also promote concept development by encouraging children to apply their developing concepts to their everyday world. These strategies are relevant during tasks as seemingly elementary as book reading. Even beginning readers must make inferences, analyze, and construct relationships in order to understand the text that they read (Resnick, 1987).

In the context of reading Goldilocks and the Three Bears, for example, a teacher may pause before turning the page at a critical moment to ask her students, “what do you think will happen next?” She might also prompt children’s thinking with questions such as “why did Goldilocks eat Papa Bear’s porridge?” and “what would you have done if you were Goldilocks?” Opportunities for analysis and problem solving can even occur in routine encounters such as behavior management. When one child upsets another, the teacher may intervene with questions such as “why do you think your friend feels sad?” or “what are some things we can do to help him feel better?” The resulting discussions advance children’s learning beyond the basic recall of facts and enable children to learn to process information and to think more effectively, habits of mind that facilitate learning and development across multiple content domains.

Unfortunately, although concept development is a desired feature of early childhood programs, it does not occur frequently in typical preschool classrooms. In a large-scale study of 250 preschool programs, classrooms received average ratings in the low- to middle-range for concept development. Classroom discussions were focused predominantly on the recall of facts, rather than on open-ended questioning (La Paro et al., 2004), and there was little support for children’s abilities to engage in higher order thinking, problem solving, and critical and creative thinking, skills that likely support children’s successful engagement in mathematical thinking. The National Council of Teachers of Mathematics (NCTM, 2000) identifies problem solving, reasoning and proof, communication, drawing connections across mathematical stands, and creating and interpreting representations of mathematical ideas as essential processes to mathematical development. All these processes require the higher order thinking skills promoted by teachers’ use of concept development.

#### Quality of Feedback

Young children are dependent upon their teachers’ feedback to advance their thinking, inform their problem solving strategies, and support their mastery of academic skills. While concept development measures teachers’ abilities to create meaningful higher order learning experiences, quality of feedback assesses teachers’ abilities to attend and respond to children’s engagement in their educational activities. These are subtle conceptual differences, and, in reality, feedback and concept development are processes that may occur simultaneously in teacher-child interactions. Teachers who provide high quality feedback are likely engaging in concept development, and teachers who engage in concept development are likely employing quality feedback strategies.

Quality of feedback is defined as “how teachers extend children’s learning through their responses about children’s learning and understanding” (La Paro et al., 2004, p. 414). High quality teacher feedback is individualized to each child’s level of performance and focuses on expanding learning and understanding, not on determining correctness or evaluating an end product (Pianta et al., 2006). Teachers providing high quality feedback assess students’ task knowledge and understanding before deciding how to next support their learning. To the child in the midst of task mastery, a teacher may re-explain, provide hints, or continue to scaffold a budding concept. To a child who has demonstrated task mastery, a teacher may offer specific praise reiterating the child’s correct actions before advancing him to the next most challenging activity. As a form of formative assessment, teacher feedback serves important functions: it guides students’ appraisals of what is important to understand, influences their motivation to learn and their perceptions of competence, consolidates their learning, and affects the development of learning strategies and skills (Crooks, 1988). Both teacher and child are engaged in an interactive form of learning.

Verbal feedback is a successful means for supporting children's learning, and is more effective than tangible feedback, such as tokens or rewards, which may distract children's attention from the immediate learning context (Barringer & Gholson, 1978). Even three-year old children demonstrate improved performance on a card sorting task when provided verbal feedback on their sorting strategies. For example, while sorting cards by shape or color, children were told "Yes, that's right, all the \_\_\_\_ go here. You're good at the (color or shape) game." or "No, that's not right. Remember, in the (color or shape) game all the \_\_\_\_ go here" (Bohlmann and Fenson, 2005, p. 125). As compared to those children who received no feedback, the feedback group sorted more accurately and was able to apply new rules to their sorting decisions. Targeted feedback enabled children to improve their task success because it guided the development of their understandings and enabled specific revisions to their problem solving strategies. Research suggests that teacher feedback should begin in the earliest years of schooling in order to promote deep, rather than surface level (e.g., recall and recognition), approaches to learning (Crooks, 1988).

Preschool teachers can engage in high quality feedback by scaffolding children's learning, providing minimal, yet sufficient, support to extend performance to the next developmental level. For example, after his teacher asks him to count the number of children sitting at circle, a child walks around the room, tapping heads and counting the number of children around him. He suddenly stops after realizing that he counted some friends more than once. The teacher recognizes his confusion, encourages him to try again and offers a new strategy to support his efforts; all children should first stand, and then sit down as he taps and counts them. On his next try, the student applies the new strategy and succeeds. As a result of the teacher's feedback, the child has not only gained practice in persisting in the face of a challenging task, but he has also learned a new strategy for use in future problem-solving efforts.

Quality feedback can also be employed when children achieve success on their own. When children "figure things out" independently, teachers can comment on the usefulness of their approaches to support and reinforce children's learning (e.g., "I like how you moved the chair out of the way so that your baby carriage could fit through the doorway"). In addition to supporting task competence, quality feedback also encourages task completion. By recognizing children's efforts and persistence through challenging tasks, teachers encourage the development of positive dispositions toward learning.

Despite its applicability to young children's learning, early educators do not maximally employ quality feedback as a feature of their instruction. Preschool teachers typically provide general praise, such as "good" or "right," as opposed to process-oriented feedback that facilitates the development of children's learning, performance, and thinking (La Paro et al., 2004). Such superficial forms of feedback have not been shown to significantly affect students' performance (Crooks, 1988) and do little to help children develop effective problem solving strategies and approaches to learning.

At the preschool level, there are few mathematical ideas that require rote or recall type understandings (e.g., two plus two makes four). Instead, preschool mathematics primarily involves reflection upon the manipulation of concrete objects (e.g., putting one duck together with two ducks to determine that one plus two makes three) and conceptual ideas (e.g., comparing the heights of two block towers to determine which is taller). To develop these types of understandings, children require teacher feedback that is attuned and responsive to the level of their conceptual understandings. Quality feedback supports children's abilities to think about problems and develop useful strategies for solving them, and encourages them to develop

positive dispositions toward learning, such as creative problem-solving approaches and persistence through challenging tasks.

### Language Modeling

Language is an essential tool for thinking and communicating. Children learn about the structure, use and content of language through their exposure to proficient language users, or language models. Given that low-income children spend an average of 5.09 hours per day in state-funded preschool programs (Howes et al., 2008), teachers are important language models for low-income preschoolers.

Language modeling refers to the extent to which teachers facilitate and support children's understanding and use of language (Pianta, La Paro, & Hamre, 2008). Teachers who engage in high quality language modeling frequently converse with students, ask open-ended questions, repeat and extend children's responses, and use advanced language forms and vocabulary with children (Pianta et al., 2006). In these ways, teachers expand children's language abilities by providing opportunities to hear complex forms of language and to use language in meaningful ways.

Teachers and children have multiple opportunities for verbal interaction throughout the day; during circle time, playtime, meal and snack time, book reading, and center time (Massey, 2004). Cross (1989) reports that preschool teachers and children spend sixty-three percent of their time engaged in conversational talk, or multiple-turn exchanges in which children were given an opportunity to participate verbally. This suggests that preschool children regularly hear and use language, in its most basic conversational forms, throughout the school day.

In addition to exposing children to general conversation in the classroom, however, teachers engaging in high quality language experiences must also provide opportunities for advanced language use, including higher-level discussions that require children to generate their own thoughts and reasoning. An example of this is cognitively challenging talk, or "talk that moves beyond the immediate conversational context," including "early literacy talk, nonpresent talk, personal narratives, and scientific talk" (Smith & Dickinson, 1994, p. 355). Although there are many opportunities for rich language use during the duration of a preschool day, teachers spend a minority of time engaging in cognitively challenging conversation (Smith & Dickinson, 1994).

In a study of children's language experiences in Head Start, Smith and Dickinson (1994) observed large variability in teachers' use of cognitively challenging talk, with children only spending an average of 8.07% (range = 0 – 49.16%) of their day engaged in this type of communication (Smith & Dickinson, 1994). As a form of decontextualized language skills, cognitively challenging talk is associated with literacy and school achievement in middle elementary school (Snow, Cancino, Gonzalez, & Shriberg, 1989). These findings reinforce the importance of high quality language modeling for children's immediate success in preschool as well as their long-term patterns of achievement.

Preschool teachers can create opportunities for rich language modeling through both full- and small-group interactions with children. At circle time, teachers often discuss a "morning message," or an idea generated by children that becomes the topic of conversation. After taking a field trip to the zoo, for example, children may discuss the morning message, "There are lots of animals at the zoo. They live there, and sleep there, and eat there, too!" The teacher displays a picture of an elephant and describes it as a "very large gray animal, with floppy ears, strong tusks, and a long trunk." After a child shouts that the elephant had a funny looking nose, the teacher says, "yes, his long nose is called a trunk. Can you all say trunk?" Next, the teacher asks

the children to each tell a story about their favorite animal at the zoo. These exchanges illustrate how teachers can structure language opportunities to be inclusive of cognitively challenging content, including scientific language, vocabulary, and personal recollections, even for young children.

Conversations with individual or small groups of children provide additional opportunities for structuring conversations and content to children's unique developmental levels and interests. While three- and four-year-olds mingle in a full-group situation, as individuals, they may have different language needs (e.g., mastering basic expression versus learning to retell a story) that are better served in more intimate conversational settings. Teachers who are good language models take into account the communication and language abilities of the children around them, and they challenge children to use advanced forms of language and to clearly and completely express their ideas and understandings. In these ways, teachers who model the use of high quality language support children's abilities to use language to think and communicate.

According to Ginsburg et al. (pp. 5-6, 2008), "mathematics education is (in part) education in language and literacy... language is required to express and justify mathematical thinking." This is particularly true in the preschool classroom, where mathematics instruction is highly interactive, heavy on discussion, and minimally reliant upon recall-type responses. Teachers who employ a diversity of language experiences, including conversing with students and exposing children to a variety of language uses and forms, are likely to succeed in supporting the development of these communication skills, which, in turn, support children's mastery of mathematical knowledge and skills. While high quality language experiences, on their own, do not necessarily advance children's mathematical knowledge, they do support skills that are necessary for the interactions that support mathematical development.

#### Specific Instruction in Mathematics

Unlike the general cognitive functions of the instructional constructs previously discussed, curriculum use and instruction are content-area specific. Curricula guide teachers in introducing mathematics to their classrooms in an intentional and supportive manner. Traditionally, mathematics instruction has been limited, both in duration and in scope, in the early childhood setting. One study (Layzer et al., 1993) observed teachers to spend 29% of morning class time on language and literacy activities and only 15% on math and science instruction combined. Further, even when teachers purposefully include mathematics in their daily curriculum, many do so in the context of daily routines (e.g., attendance, lunch and snack times), rather than in a focused and extended way (Lee & Ginsburg, 2007a). Many teachers, however, look to improve their mathematical instruction and welcome the support and guidance that curricula can offer. One teacher noted

I think that a math curricula and materials can help a teacher introduce math. It's got to be a teacher-friendly, child-friendly math curriculum that teachers can begin to use in the classroom to help young children learn and also help to broaden their ideas for math, because there are some people who want to teach these little 4-year-olds math but just don't know how to do it. (Lee & Ginsburg, 2007a, p. 121)

Many research-based preschool curriculum projects have been effective in advancing the mathematical knowledge of low-income children (e.g., Arnold, Fisher, Doctoroff, & Dobbs, 2002; Griffin & Case, 1997; Klein, Starkey, & Ramirez, 2002) by providing both curriculum activities for students and professional development activities for teachers, who often have little training in children's early mathematical development (Copley, 2004).

A classroom's adoption of a mathematics curriculum, however, does not ensure productive mathematical experiences for children. Even when teachers implement the same curriculum, as may be the case in regulated organizations such as Head Start, teachers' differential implementation patterns may influence children's developmental outcomes. Such variations reflect individual teachers' unique abilities and efforts to support children's mathematical development. Despite the recent increase in mathematical curriculum research, few studies have addressed the specific implementation features and instructional strategies that contribute to differential mathematical outcomes (Golbeck, 2001). Such knowledge would advance the field of early mathematical development and would support teachers in their efforts to maximize student gains.

Currently, no instruments are commercially available to measure the quality of mathematical instruction, although observation tools such as the Early Language Literacy Classroom Observation (ELLCO; Smith & Dickinson, 2002) exist to measure the quality of language and literacy practices in the preschool classroom. This study will measure the effects of teachers' specific instruction in mathematics on children's mathematical development by considering the intensity and fidelity of curriculum implementation. All teachers in this study used the same curriculum, yet teachers varied in the number of activities completed and on ratings of implementation accuracy.

The intensity with which a teacher implements a mathematics curriculum reflects the amount of exposure students have to focused mathematical instruction in the classroom (e.g., the number of curricular activities provided per child). Since mathematics has not traditionally been a primary content area of preschool programs, there may be large variability in the number of planned and structured experiences teachers provide for children to develop mathematical competencies. The accuracy with which teachers teach a curriculum is captured by measures of curriculum fidelity, which assesses the degree to which teachers implement activities as instructed by curriculum developers. To be most effective, teachers should not only provide opportunities for mathematical instruction (i.e., high intensity), but should also provide meaningful and appropriate instruction specific to the learning activities (i.e., high fidelity). Since teachers are often underprepared to support early mathematical development (Copley, 2004), differences in their abilities and efforts to provide mathematical learning experiences, even with the guidance of a curriculum, will likely have important effects on children's mathematical development. Teachers' pedagogical orientations and expectations for the role of the preschool may also influence their implementation patterns.

In one of the first studies to specifically explore preschool teachers' pedagogical beliefs about math and literacy subject areas, Lee and Ginsburg (2007a) found that teachers' appreciations for specific instruction in mathematics varied depending on the demographics of the students they served. As compared to teachers of middle-SES preschoolers, teachers of low-SES children, like those in this study, more strongly believed that academic preparation should be a primary goal of early education, and that this should be supported with teachers' effortful plans for mathematics and literacy instruction. Teachers of low-SES children also expressed a greater appreciation for the importance of early mathematics education and had a more positive attitude towards the use of math curricula than did teachers of middle-SES children, who viewed the role of preschools as that of social nurturance. As compared to the teachers of low-SES children, however, teachers of middle-SES children were more sensitive to individually appropriate instructional practices and were also more respectful of children's interests and preferences.

According to Lee and Ginsburg (2007a), the pedagogical differences between the teacher groups could be attributed to the unique characteristics of the populations they serve, with teachers of low-SES students believing that, due to socioeconomic disadvantage, their children may not receive sufficient educational support at home. Further, teachers serving low-SES children are often employed by public agencies that have already adopted the more academic orientation toward preschool education through their affiliation with state and federal policies. Teachers of middle-SES children, on the other hand, may be employed by private preschools and may continue to hold more traditional beliefs about the socialization purposes of early childhood education.

While many teachers now recognize the role of mathematics in early childhood education, teachers' actual mathematical practices and the effects of their instructional strategies are yet to be explored. Today, most teachers of both low- and middle-SES children recognize society's increased academic expectations for young children and value a mathematics education that is both fun and stress-free (Lee & Ginsburg, 2007b). Teachers of low-income children, however, express a stronger appreciation for mathematics as a priority of preschool education and recognize the importance of their role in facilitating this type of learning (Lee & Ginsburg, 2007a). This study contributes to the literature by further exploring such teachers' actual instructional practices, in mathematics and in general cognitive support, and their relationship to children's mathematical development.

#### Summary

Few studies have examined the specific classroom instructional practices that maximally support children's mathematical development. Even in the context of curricular interventions, analyses have not been conducted to determine the particular implementation features associated with optimal mathematical knowledge growth. By evaluating the effects of teachers' general cognitive practices and specific instruction in mathematics on low-income children's mathematical development, this study adds a necessary refinement to our understanding of classroom quality and early mathematics education. An examination of these processes, as well as the effects of children's age, existing math knowledge, and ELL status, will further clarify the particular instructional features that lead to developmental advantages.

#### Conceptual Model

This study's conceptual model (see Figure 1) details the relationship between the constructs used to investigate the influence of child factors and teachers' instructional practices on children's mathematical development during the preschool year. Child-level factors included age, pre-existing mathematical knowledge, ELL stats, and the intensity of the experienced curriculum. Three sets of classroom-level predictor variables included general classroom quality, general cognitive practices and specific instruction in mathematics. The general cognitive practice variables were concept development, quality of feedback, and language modeling. Variables for specific instruction in mathematics included implementation intensity and implementation fidelity. The dependent variable was children's mathematical development.

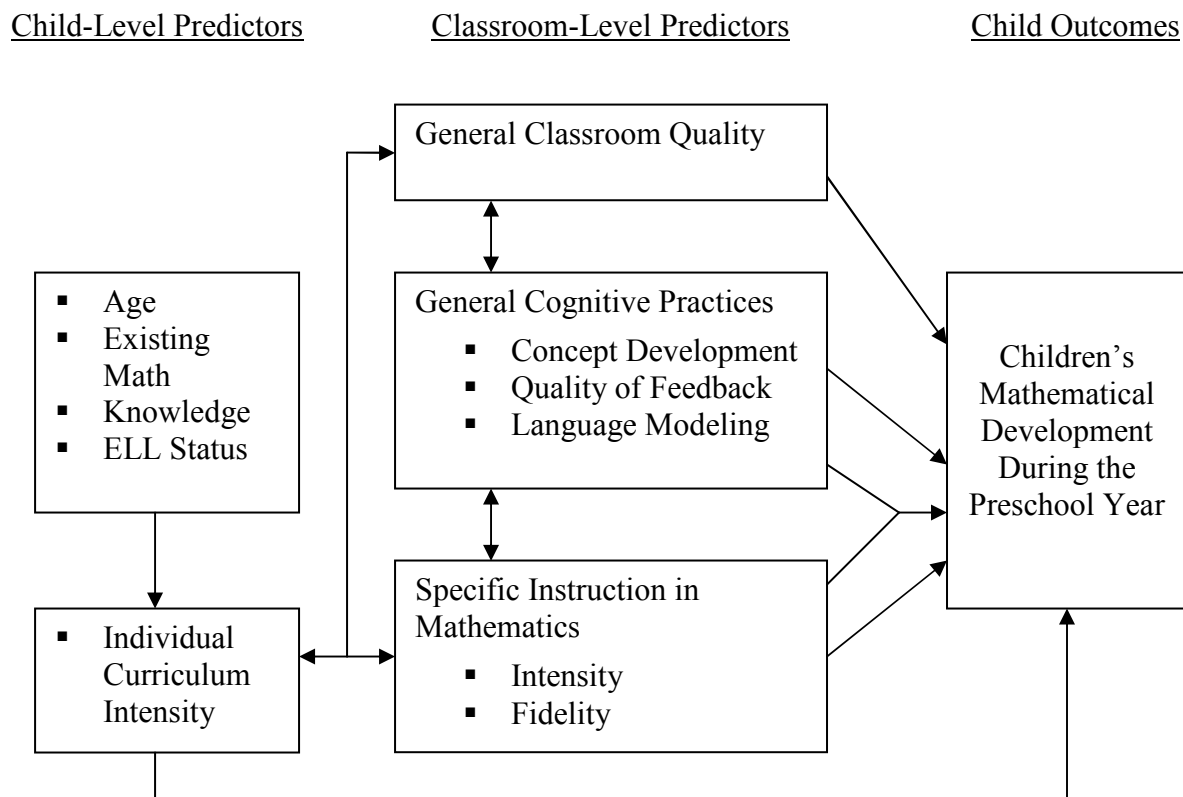


Figure 1. Conceptual model of the instructional practices influencing mathematical development

The unidirectional arrow from each set of predictor variables to the outcome indicates that each variable set may independently predict children's mathematical development during the preschool year. The unidirectional arrows relating children's age, existing mathematical knowledge, and ELL status to individual curriculum intensity indicates that individualized curricula reflect student attributes. The two-pronged unidirectional arrow indicates that general cognitive practices may moderate the influence of specific instruction in mathematics on mathematical development. Bidirectional arrows link the predictor variables, indicating that, as individual components of the broader concept of classroom quality, they are likely somewhat interdependent and strength in one area may influence the strength of another. This model describes the primary research questions, which explore the contrasting contributions of general and specific instructional practices to children's mathematical knowledge growth.

Control variables. In order to examine the specific influence of instructional quality on the outcome variable, general classroom quality was controlled for in classroom-level analyses. The time interval between tests was also entered as a control variable due to its positive correlation with children's pre- to post-test score gains. Although not included as a control, teachers' education was considered as a classroom-level control variable because teachers' educational experiences have been found to influence the quality of their instruction, with more prepared teachers demonstrating greater confidence and success in the classroom than teachers with little education and training (Darling-Hammond, 2000). However, although less educated teachers are often over-represented in classrooms serving minority and low-income children (National Commission on Teaching and America's Future [NCTAF], 1996), teachers in this



sample were generally very well educated, either having earned bachelor's or master's degrees. Further, teachers' education was not correlated with classroom averages for curriculum intensity or mathematical gain scores.

#### Research Questions and Hypotheses

Using quantitative data collected from child assessments, classroom observations, and teacher surveys, five research questions were addressed by this study. Together, they investigated the influence of the contrasting contributions of general and specific mathematical support practices on preschool children's mathematical development. The first question explored the relationship among three indicators of instructional quality: general classroom, general cognitive, and mathematics-specific quality. The second question determined the influence of both general cognitive practices and specific instruction in mathematics on children's mathematical development, controlling for general classroom quality, while the third question addressed the independent contribution of specific instruction in mathematics after general cognitive instructional and classroom quality were taken into account. Because both instructional processes were hypothesized to influence mathematical development, however, the fourth question considered whether general cognitive practices moderate the effect of specific instruction in mathematics on preschool children's mathematical development. To account for the influence of child-level factors on mathematical development, the final research question examined the influence of age, existing mathematical knowledge, and English language learner status on curricular experiences and mathematical knowledge growth across the preschool year.

#### Relationship among Quality Measures

The first research question explored the relationship among three different quality indices: general classroom environment quality, general cognitive support practices, and specific instruction in mathematics. The question was: to what extent are general classroom quality, general cognitive practices, and specific instruction in mathematics related to each other?

Although strengths in global quality (e.g., emotional climate, behavior management and an organized and well-stocked physical environment) likely provide the structure for high quality teacher-child instructional interactions, in line with previous findings (Frede et al., 2007), I expected only modest correlations between general classroom environment quality and the process measures of quality: general cognitive practices and specific instruction in mathematics. General classroom environment measures a global construct that includes broad measures of structural and process classroom features, including the physical arrangement and overall classroom climate. Therefore, it is not likely to be highly correlated with processes focused on student learning, such as general cognitive practices and specific instruction in mathematics. For example, while certain physical features of the classroom environment may be easily shared across multiple classroom environments (e.g., materials), general cognitive practices and specific instruction in mathematics reflect each teacher's autonomous influence on the classroom environment.

I expected general cognitive practices and specific instruction in mathematics, however, to be moderately correlated because both are measures of instructional interactions related to cognitive development. Teachers whose pedagogical orientations are toward supporting school readiness are likely to behave in ways that promote student learning. I did not expect them to be highly correlated due to the fact that general cognitive practices focus more on general cognitive growth, while specific instruction in mathematics capture mathematics-specific instruction. Some teachers may place a high priority on supporting general thinking skills, but may not do so for mathematical skills, which are sometimes perceived as being inappropriate for preschool

aged children (Copley, 2004). Others may resist specific curricular activities and interactions due to discomfort or time or staffing constraints, yet may easily engage in general cognitive practices throughout the course of their regular school day.

#### Influence of General Cognitive and Mathematics-Specific Instructional Practices

The second research question investigated whether general cognitive practices and specific instruction in mathematics predict children's mathematical growth. These variables measure support for two essential components of mathematical knowledge: general cognitive development and mathematical content knowledge. Specifically, the question asked: controlling for general classroom quality, do general cognitive practices and specific instruction in mathematics predict children's mathematical development?

An understanding of mathematics requires both knowledge of mathematical content and mastery of the thought processes required to mentally manipulate it (Resnick, 1989). Young children's knowledge of mathematical content logically benefits from the direct instruction of certain skills and concepts. Therefore, the quality of mathematical curricular experiences should influence children's familiarity with and their mastery of these skills, leading to differential performance on the outcome measure. Furthermore, the National Council of Teachers of Mathematics (NCTM, 2000) recognizes the following general cognitive processes as essential to mathematical fluency: problem solving, reasoning and proof, communication, drawing connections across mathematical stands, and creating and interpreting representations of mathematical ideas. These processes will likely be dependent upon a child's experience with higher order thinking and with the cognitive support they received through teacher-child interactions, as captured by the general cognitive practices construct. I expected that teachers who rate highly on general cognitive practices and specific instruction in mathematics would have students who experience greater mathematical growth during the preschool year than teachers who rate low on these instructional interactions.

The third research question investigated the independent influence of specific instruction in mathematics on children's mathematical growth. The question asked: what is the independent contribution of specific instruction in mathematics after general classroom quality and general cognitive practices have been taken into account?

Mathematics curricula are considered to be essential components of early childhood mathematics education (Ginsburg et al., 2008). Yet, curricula, on their own, do not ensure children's learning. This question evaluates the effects of teachers' differential implementation patterns on children's mathematical development. I predicted that specific instruction in mathematics, as measured by the quality of curriculum fidelity and intensity, would significantly predict children's mathematical development across the preschool year, even after controlling for the influences of general classroom quality and general instructional quality. Teachers who are willing and able to accurately and frequently engage in curriculum activities will likely have students who achieve greater mathematical gains during the preschool year due to their familiarity with the content and practice with mathematical skills.

#### Moderating Effects of General Cognitive Practices on Specific Instruction in Mathematics

To further specify the relationship between general thinking skills, specific mathematical content, and children's mathematical development, I addressed the possibility of a moderating effect of general cognitive practices on the effects of specific instruction in mathematics on children's mathematical growth. The fourth research question was: do general cognitive practices moderate the effect of specific instruction in mathematics on children's mathematics

development? This provides insight into how these two variables work together to predict children's mathematical development during the preschool year.

Teachers demonstrate various patterns of instructional strengths, reflecting individual skill levels and pedagogical differences about the inclusion of academics in early childhood (Baroody et al.; Copley 2004). This variability in instructional quality allowed the following questions to be addressed: Does the strength of the relationship between specific instruction in mathematics and children's mathematic development increase when general cognitive practices are high, as well? Does the relationship weaken when general cognitive practices are absent or of low quality?

I hypothesized that children's abilities to engage in higher order thinking and to mentally manipulate facts and problems would influence the extent to which they benefit from mathematical curricular experiences. For example, although specific instruction in mathematics may be a significant predictor of children's mathematical growth for all values of general cognitive practices, the strength of the association could increase when general cognitive practices are high, indicating that it is the combination of factors that optimally supports mathematical development in the preschool year. Therefore, I predicted that general cognitive practices would moderate the effect of specific instruction in mathematics because both are necessary processes in children's understanding and application of mathematical knowledge.

Effects of Children's Age, Existing Mathematical Knowledge, and English Language Learner Status on Curricular Experiences and Mathematical Development

Teachers' instructional practices are only one influential aspect of a child's early mathematical experience. Children bring to their classroom a number of influential attributes, including age, variations in previous mathematical experience, and language status. These characteristics likely influence children's subsequent learning experiences.

I hypothesized that older children may exhibit greater mathematical knowledge at pre-test, but not necessarily greater mathematical growth over the preschool year. Children demonstrating greater knowledge at pre-test likely received more intense curricular experiences than children demonstrating less, and English language learners (ELL) likely received less intense curricular experiences and made fewer mathematical gains from pre-test to post-test than did children whose primary language was English.

## CHAPTER 3. METHODS

### Larger Study Design

This study is a sub-study of an Early Reading First (ERF) project at the University of Hawai'i. The ERF project was a three-year collaborative effort between the University of Hawai'i Center on the Family, the Honolulu Community Action Program - O'ahu Head Start and the State of Hawai'i Department of Education. Funding was derived from the U.S. Department of Education and it provided participant Head Start teachers with training on the Learning Connections (LC) curriculum (DeBaryshe & Gorecki, 2007; DeBaryshe & Gorecki, 2005), relevant classroom materials, ongoing coaching support, and professional development opportunities for the purpose of enhancing the literacy and numeracy environments of their classrooms. The project was conducted between the 2005 and 2008 school years.

The effectiveness of the LC curriculum has been demonstrated in two validation studies. Children in LC classrooms showed greater gains on performance measures of emergent reading, phonemic awareness, letter-sound correspondence, emergent writing, and math skills than children enrolled in classrooms implementing either a teacher-designed curriculum or the Creative Curriculum (DeBaryshe & Gorecki, 2005; Sophian, 2004). Effect sizes ranged from .21 to .81 *SD*, with LC being particularly effective for ELL children. LC curriculum goals were based on a thorough review of research on developmental processes and early childhood pedagogy [e.g., International Reading Association (IRA) and NAEYC, 1998; Ginsburg, Klein, & Starkey, 1998; NAEYC & NCTM, 2002; NCTM, 2000; Snow, Burns, & Griffin, 1998]. (See Appendix A)

Throughout my three-year involvement with the ERF project, I developed and sequenced activities for the mathematics curriculum and assisted in training project teachers in its implementation. I also conducted language, literacy, and mathematics assessments with participant children and conducted classroom observations. Finally, I managed the project databases, as well as assisted the Principal Investigator with data analyses and project reports.

### Recruitment Procedures

Teachers were recruited through their employer, Honolulu Community Action Program - O'ahu Head Start, a project partner, which invited all preschool teachers to express interest in becoming involved. Participation included involvement in curriculum training, implementation, coaching, and evaluation, as well as attendance at professional development classes and distribution of educational home activities to parents throughout the school year. Aside from the potential benefits to their classroom environment and improvements in instructional quality, teachers were attracted to participate by the professional development opportunities, including college coursework for credit. The final 17 participant teachers and their classrooms were selected from the list of teacher volunteers based on the following criteria: (a) location of the classroom site within the attendance boundaries of a Reading First public elementary school, (b) teacher credentials and experience, and (c) staff willingness to serve as role models for other OHS teachers and community preschool programs.

Once the 17 classrooms were selected, informational flyers and consent forms were distributed to parents of children enrolled at those sites. The flyers briefly explained that the goal of the Early Reading First project was to assist teachers in improving the quality of their instruction, their classroom environments, and their partnerships with parents for the purposes of increasing student achievement in language, literacy, and mathematics. Parents were asked for permission to allow project staff to assess their children's language, literacy, and mathematical performance at the beginning and end of the school year, to observe their children in the

classroom and to collect samples of children's school work and home activities. Parents were also asked to complete a survey at the beginning and end of the year about their children's learning at home. Parents who agreed to these requests signed and returned the consent form. The consent rate was high at 98%.

#### Sample Characteristics

This study includes six school sites, 17 Head Start classrooms, and 205 participant children from the 2006-2007 and 2007-2008 school years. For the current study, the larger-study sample was restricted to those children who were a minimum of 3-years-old at pre-test and a maximum of 6-years-old at post-test because the Developing Skills Checklist (DSC), the outcome measure of mathematical development, is standardized and validated only for children aged 3-years-old through 5-years-old. The sample was also limited by the availability of each child's pre- and post-test performance data on the DSC. The 205 children in this study represent 82% of the original sample of 251. Children ranged between ages 3 years 0 months and 4 years 8 months at pre-test ( $M = 3$  years 9 months,  $SD = 5$  months) and 3 years 7 months and 5 years 5 months at post-test ( $M = 4$  years 6 months,  $SD = 6$  months).

All of the participant children lived in poverty, which was identified by a monthly income less than \$1687 for a family of three. Forty four percent of participant children were Native Hawaiian, 25% Asian American, 20% Pacific Islander, 4% Hispanic, 2% Black, 2% Alaskan or American Indian, 1% White, and 2% did not report an ethnic background. Twenty-four percent of the children were English language learners, as reported by parents and defined by the predominance of a foreign language at home.

#### Measures

The research design utilized quantitative measures, including child assessments, classroom observations, and teacher belief surveys, to address the study's main question: what is the relation of general cognitive support and specific instruction in mathematics to children's mathematical development during the preschool year?

Data were collected in the 2006-2007 and 2007-2008 pre-kindergarten school years. In the early fall and late spring, direct assessments of children's mathematical skills were conducted using the DSC. Three classroom observations were conducted each year using the Early Language Literacy Classroom Observation (ELLCO). These occurred during the months of September, January, and May. Throughout each school year, teachers documented their students' exposure to and mastery of curricular activities on the LC Mathematical Activity Log, and full-time project coaches assessed teachers' implementation of curriculum activities on a monthly basis using the LC Fidelity Rating Scale. Although teachers were expected to implement the curricular activities listed on the project lesson plans each week, teachers were free to return to previous activities and implement additional curricular activities as needed to individualize the curriculum to each child's developmental level. Finally, at the beginning of each preschool year, teachers completed the Instructional Belief Scale, reporting their beliefs about preschoolers' development and appropriate instructional pedagogy. (See Appendix B for a summary and explanation of the study variables.)

#### Classroom Observations

##### Early Language Literacy Classroom Observation – General Classroom Environment

The ELLCO (Smith & Dickinson, 2002) is a widely used measure of classroom quality and language and literacy classroom practices. The ELLCO's Classroom Observation score is comprised of two subscales: General Classroom Environment (GCE) and Language, Literacy,

and Curriculum. The GCE subscale was used as a global measure of classroom quality to capture overall structural and process quality in each of the classrooms.

The GCE composite is comprised of five item ratings: classroom organization, classroom contents, opportunities for child choice and initiative, classroom management strategies, and classroom climate. The GCE composite has good internal consistency, with an alpha coefficient of .83. Each of the items is rated on a Likert-type five-point scale. Examples of teacher behaviors and classroom features are provided for ratings of 1 (quality deficiencies), 3 (basic quality), and 5 (exemplary quality) to assist observers in making accurate scoring decisions. The observation period lasted between an hour and an hour-and-a-half, and a 10 minute post-observation teacher interview was conducted to provide supplemental information necessary to complete the item ratings.

Each school year, a local certified ELLCO trainer conducted a one-day training for all ELLCO observers. Under the supervision of the certified trainer, observers then conducted practice ELLCO observations in non-study preschool classrooms and established inter-rater reliabilities above .80. Observers then visited project classrooms to collect ELLCO data. During data collection, observers achieved inter-rater reliability estimates of .86 in year 1 and .90 in year 2. (See Appendix C)

Because ELLCO observations were conducted three times during the year (fall, winter and spring), an average score was computed to represent the general classroom environment scale for each participant classroom.

#### Classroom Assessment Scoring System – Instructional Interactions

The Classroom Assessment Scoring System (CLASS) is an observational assessment of a classroom's emotional and instructional climate (Pianta, La Paro & Hamre, 2006). Rather than focusing on the stationary features of the classroom or on broad descriptors of social interactions, the CLASS places an emphasis on specific emotional and instructional features of teachers' interactions with children and teachers' use of classroom materials. The CLASS observation tool consists of nine constructs across three scales: Emotional Support, Classroom Organization, and Instructional Support. The Emotional Support scale, or social-emotional constructs, include: (a) positive emotional climate, (b) negative emotional climate, and (c) teacher sensitivity. The Classroom Organization scale, or management constructs, include: (d) overcontrol, (e) behavior management, and (f) productivity. The Instructional Support scale includes the following constructs: (g) concept development, (h) quality of feedback, and (i) language modeling. Because Instructional Support has been found to be the most robust dimension of the CLASS for predicting growth in children's expressive language, pre-reading concepts, and applied mathematics skills (Hamre, et al., n.d.), it was selected to measure the quality of teachers' support for children's general cognitive development.

The Instructional Support scale assesses the degree to which teachers promote conceptual development and use explicit feedback and rich language to support children's cognitive development. The specific instructional support constructs included are (a) concept development, (b) quality of feedback, and (c) language modeling. Each of the three instructional constructs was rated on a Likert-type seven-point scale. Ratings of 1 or 2 indicate low quality, ratings of 3, 4, and 5 indicate moderate quality, and ratings of 6 and 7 indicate high quality. Indicators and examples of teacher behaviors and classroom features for each grade level were provided to assist observers in making accurate ratings. Classrooms were observed and rated on all construct items for each of five 20-minute cycles. Ratings for each scale were averaged across the five cycles to obtain a single score for each scale.

Concept development ratings refer to “the degree to which teachers promote higher-order thinking and problem solving, going beyond fact and recall discussions with children” (La Paro et al., 2004, p. 414). This construct does not necessarily reflect the development of specific concepts (e.g., weather or adding), but captures teachers’ use of instructional strategies that encourage students’ understanding and thinking skills, rather than those that focus on rote instruction. Examples of high concept development include linking current activities to previous ideas, helping children apply information to their own lives, and asking thought-provoking questions such as “Why do you think the bears had to store food for the winter?” and “What are some of the things that might happen if they did not have food during the winter?” (Pianta et al., 2006, p. 64). Examples of low concept development include asking recall-type questions, such as “What animal was in this story?” and “What did the frog need to build a house?” and failing to relate concepts to children’s real world experiences, such as teaching what the letter “T” looks and sounds like, but failing to discuss how the letter appears in familiar words (Pianta et al., 2006, p. 60).

Quality of feedback ratings reflect “how teachers extend children’s learning through their responses about children’s learning and understanding” (La Paro et al., 2004, p. 414). High quality teacher feedback includes responses to children’s work that are focused on expanding children’s learning and understanding, not on determining correctness or evaluating an end product (Pianta et al., 2006). Examples of high quality of feedback include “Tell me about your painting – how did you decide to put the birds in the picture” or “When you put that much water in the pot the dirt gets so wet that the seed can’t grow very well. Let’s try it again with a little less water so that the seed can grow up to be a plant” (Pianta, et al., 2006, p. 70). Examples of low quality of feedback include failing to lead children toward understandings of new ideas and the use of general praise such as “yes,” “no,” “nice work” or “that’s beautiful” (Pianta, et al., 2006, p. 68).

Language modeling ratings refer to the extent to which teachers facilitate and support children’s understanding and use of language (Pianta, La Paro, & Hamre, 2008). Teachers who engage in high quality language modeling frequently converse with students, ask open-ended questions, repeat and extend children’s responses, and use advanced language forms and vocabulary with children (Pianta et al., 2006). Examples of high language modeling include asking many open-ended questions, commenting on children’s actions, such as “You are putting a dress on that baby doll and making her look very pretty and all dressed-up,” and advancing children’s language using more sophisticated forms, such as “You have many different colors in your hat. It’s a multi-colored hat” (Pianta et al., 2006, p. 77). Examples of low language modeling include asking questions with one-word answers, failing to describe children’s actions through parallel talk, or responding to children’s comments with simple phrases such as “Yes, it’s a bird.”

Based on several national studies, the instructional support composite has demonstrated good internal consistency, with alpha coefficients ranging between .79 and .91 and test-retest reliabilities ranging between .81 and .86 (Hamre et al., n.d.). (See Appendix C)

CLASS observers were trained on the instrument by a certified CLASS trainer and achieved inter-rater reliability estimates of .89 during year 1 and .87 during year 2 data collection periods.

CLASS observations were conducted three times during each school year (fall, winter and spring). An average score was computed for the instructional support variables for each participant classroom.

## LC Curriculum Measures

### Mathematics Activity Log – Curriculum Intensity

Teachers recorded each child's exposure to and mastery of mathematics curriculum activities on the LC Mathematics Activity Log (see Appendix D). This measure is a type of formative assessment that tracks students' mathematical knowledge and supports teachers' efforts to individualize instruction to meet each child's developmental needs. Teachers used this check-sheet to document children's performance on each of the curricular activities and to rate children's conceptual understanding of each activity at one of three levels: introductory, in progress, or mastery. Since teachers often presented curricular activities more than once, children's performance levels were updated after each exposure.

The information from the activity log was used to determine the intensity with which each teacher administered the mathematics curriculum. The intensity variable was determined by taking into account both the number of activities introduced and the conceptual depth of content coverage. It was computed by multiplying each child's number of activities at each conceptual performance level (i.e., introductory, in progress, mastery) by a corresponding numerical value (i.e., introductory understandings were scored as 1, in progress understandings were scored as 2, and mastery understandings were scored as 3). These values were then summed, representing each child's individual curriculum intensity level. Classroom means were then computed for the average intensity level attained by each teacher. This variable provides insight into the intensity of mathematical activities and content teachers provided to their students.

### Fidelity Rating Scale – Curriculum Fidelity

The quality of LC instruction was measured using the LC Fidelity Rating Scale (see Appendix E). Once a month, each teacher was observed teaching an LC activity and the quality of her implementation was rated by a project coach. One item measures classroom-level materials preparation and four items measure the accuracy of lesson delivery, successful scaffolding and individualization, and child engagement ( $\alpha = .91$  for the latter 4 items,  $\alpha = .76$  for 5 items). Each item was rated on a five-point scale. Ratings of 1 or 2 indicated poor fidelity, ratings of 3 indicated fidelity in-progress, and ratings of 4 or 5 indicated fidelity mastery. Fidelity rating scores for mathematical activities were averaged over the year to provide an average curriculum fidelity score for each teacher. Fidelity scores were based on an average of 5.7 fidelity ratings ( $R = 5 - 9$ ) per teacher. This variable reflects the quality with which teachers implemented their mathematical curriculum activities, in terms of accuracy of delivery and support provided for children's learning.

### Instructional Belief Scale

Currently, no measures of teacher cognition exist in the areas of early literacy and mathematical development and pedagogy that are both consistent with the Learning Connections curriculum philosophy and have well-established psychometric properties. Therefore, a project survey was developed to measure teachers' beliefs about preschoolers' development and appropriate instructional pedagogy.

The Instructional Belief Scale (see Appendix F) is a 14-item survey ( $\alpha = .77$ ) that measures teachers' appreciation for supporting preschoolers' language, literacy, and mathematical knowledge growth. Teachers rated their agreement with developmental and pedagogical statements on a five-point Likert rating scale (strongly disagree to strongly agree). Sample items include: "It is important to adjust an activity to each child's level" and "Appropriate math content for preschoolers largely focuses on counting and numeral



recognition.” (Note that some items, such as the latter example, are reverse scored.) Scores on the scale correlate with teachers’ education levels ( $r = .51$ ) and years of teaching experience ( $r = .45$ ).

In its entirety, the scale reflects the strength of teachers’ academic orientations in their preschool teaching. For example, teachers rating highly on the scale tend to believe in children’s academic learning capacities; preschoolers are capable of appreciating environmental print, using inventive spelling, counting, and understanding concepts such as graphing and volume. They also tend to agree that teachers should join children in their activities, scaffold their learning, and engage in literacy and mathematical instruction with children. Teachers rating low on the scale, in contrast, may have lower expectations for preschool children’s academic abilities, may see literacy and mathematical development as elementary school tasks, and may assume a more passive or supervisory role in monitoring learning in their classrooms.

Five of the 14 survey questions are specific to mathematical development. These questions measured teachers’ appreciation for preschoolers’ mathematical capacities in the areas of number, operations, geometry, measurement, and data representation. In addition to examining teachers’ overall orientation to academics in preschool, their belief scores were measured as they related specifically to mathematical development and instruction. Teachers may understand and embrace literacy and mathematical instruction differently, so a separate Mathematical Belief Scale score was computed using the subset of mathematics-related questions.

#### Child Assessments

##### Developing Skills Checklist – Mathematics and Logical Operations Subscale

The DSC Mathematics and Logical Operations subscale measures children’s emergent math abilities, assessing skills in the areas of numbers and operations, geometry and spatial sense, and measurement (CTB/McGraw-Hill, 1990). It is a researcher administered instrument consisting of 36 items and is standardized and normed for Spring performance for children aged 3-years-old to 5-years-old. Children were asked to identify basic shapes, copy and extend simple patterns, perform various counting tasks, identify numerals, create sets of objects, identify ordinal positions, and perform logical reasoning tasks, such as classifying objects by shape, estimating, and seriating. Raw scores were used in this study, since norms are not available for scores at pre-test. The DSC mathematics scale has strong inter-item consistency ( $K-R 20 = .89$ ,  $SEM = 2.27$ ) and convergent validity with the ESA mathematics achievement scale ( $r = .59 - .73$ ). (See Appendix C)

The DSC was one of four instruments included in the larger study’s battery of assessments, administered to measure children’s language, literacy, and mathematics skills. Due to the short attention spans of preschool aged children, the battery of instruments was administered in two sessions of 25-30 minute durations. The order of test administration was counterbalanced. The time for administration of the DSC, alone, was approximately 10-15 minutes per child.

To ensure the quality of assessment data, child assessors participated in a one-day training on the administration of the assessment instruments and appropriate testing procedures for preschool aged children. Child assessors were trained by project staff prior to data collection at both pre- and post-test. After the training, assessors conducted practice assessments at a non-study preschool and were observed by training staff. Once the assessors demonstrated proper administration procedures and accurate data recording and scoring, they were certified to begin assessments in participant classrooms.

Table 1  
Variable Descriptions

	Description	Data Measurements
Classroom-Level Variables		
General Classroom Environment Quality	ELLCO Observational Ratings	0 – 5.0 points
General Cognitive Processes	CLASS Instructional Support Subscale – Concept Development, Quality of Feedback, and Language Modeling	0 – 5.0 points
Specific Instruction in Mathematics		
▪ Curriculum Depth (Classroom Average)	▪ Number of completed activities and levels of mastery demonstrated per child	▪ 0 – 423.0 points
▪ Curriculum Number of Activities (Classroom Average)	▪ Number of complete activities per child	▪ 0 – 141.0 points
▪ Curriculum Fidelity	▪ Teachers' ratings on accuracy of curriculum implementation – average across all ratings	▪ 0 – 5.0 points
Teacher Education	Highest educational level attained	1 = A.A. 2 = B.A. 3 = M.A. or Higher
Teacher Belief Score	Percent agreement with statements about the appropriateness of academic and mathematics in preschool	▪ 0 – 1.0 ▪ 0 – 1.0
Child-Level Variables		
Mathematical Development	Change in performance from pre-test to post-test on the DSC	-36.0 – 36.0 points
Initial Mathematical Knowledge	Mathematical performance at pre-test on the DSC	0 – 36.0 points
Curriculum Depth (Individual Score)	Number of completed activities and levels of mastery demonstrated	0 – 423.0 points
Curriculum Number of Activities	Number of complete activities	0 – 141.0 points
Testing Time Interval	Time interval between pre- and post-test	Measured in months
Gender	Male or female	0 = Male 1 = Female
ELL Status	English language learner (primarily a foreign language at home) or not	0 = ELL 1 = Not ELL
Age	Child's age at pre-test	Measured in months

### Analytic Strategies

Statistical analysis procedures were used to analyze the quantitative data. All child- and classroom-level data were entered into SPSS for preliminary data analysis. Subsequent multi-level analyses were conducted using HLM.

First, the independent variables were examined to determine whether composite variables could be created to represent the overarching constructs: general cognitive practices and specific instruction in mathematics. To determine whether the three component variables representing general cognitive practices (i.e., concept development, quality of feedback, and language modeling) could be collapsed into a single composite variable, intercorrelations were computed. Results indicate that two of the three associations are significant at the .01 and .05 levels. The third association approaches significance, with a  $p$  value of .08. Because the variables are well correlated, each classroom's concept development, quality of feedback, and language modeling scores were combined; scores were added together to create a composite variable representing general cognitive practices.

Table 2  
Correlation Matrix for General Cognitive Practice Variables

Variable	1	2	3
Classrooms (n = 17)			
1. Concept Development	----	.72*	.58
2. Quality of Feedback		----	.84**
3. Language Modeling			----

\*\*  $p < 0.01$ . \*  $p < 0.05$ .

The individual variables measuring mathematics curriculum quality were correlated to determine whether a composite variable could be created for specific instruction in mathematics as well. Teachers' average fidelity ratings were not significantly correlated with the average intensity of their curricular activities. The Pearson correlation coefficient for this association was .52, with  $p = .13$ , indicating a non-significant association. Because these variables were not significantly correlated, they were entered as separate predictors in analyses involving the specific instruction in mathematics construct.

Next, the research questions were addressed. Correlational analyses were obtained to explore the associations across general classroom quality, general cognitive practices, and specific instruction in mathematics. Multi-level analyses were then utilized to explore the independent and moderator relationships among the variables of interest and the outcome measure, children's mathematical development. To further explore the pattern of findings, analyses were conducted to determine whether teacher beliefs about academic and mathematical pedagogy were associated with the quality of their general cognitive practices, curriculum fidelity or curriculum intensity. Finally, multi-level analyses were conducted to determine the

influence of age, existing mathematical knowledge, and ELL status on children's curricular experiences and mathematical development. These findings will be discussed in the next chapter.

## CHAPTER 4. RESULTS

This chapter describes the results of the study. Results are discussed in relation to the five research questions: (a) to what extent are general classroom quality, general cognitive practices, and specific instruction in mathematics related to each other?; (b) controlling for general classroom quality, do general cognitive practices and specific instruction in mathematics predict children's mathematical development?; (c) what is the independent contribution of specific instruction in mathematics after general cognitive practices have been taken into account?; (d) do general cognitive practices moderate the effect of specific instruction in mathematics on children's mathematics development?; and (e) what is the influence of children's age, pre-test mathematical knowledge, and English language learner status on their curricular experiences and mathematical development across the preschool year?

First, descriptive statistics and correlational analyses are presented. Next, the findings for the five main research questions are discussed.

### Descriptive Statistics

Descriptive statistics for the continuous independent and dependent variables were computed. These data are presented in Table 3. Inspection of these data indicates variability on most predictor measures. At the classroom-level, teachers varied in the general quality of the classrooms, their levels of cognitive support, their fidelity and intensity of curriculum implementation, and their academic and mathematical beliefs. At the individual-level, children varied widely in the intensity of curriculum received and in their mathematical gain scores, the outcome variable. This supports the hypotheses that differences in instructional quality vary at the classroom- and child-levels, and that these variations may influence children's differential development of mathematical skills and understanding during the preschool year. Examination of teachers' educational levels indicated that greater than 90% were educated with a bachelor's degree or higher. Therefore, education was excluded as an explanatory variable. Six percent of lead teachers held an associate's degree, 76% held a bachelor's degree and 18% held a master's degree in early childhood education or human development.

Table 3  
Descriptive Statistics for the Independent and Dependent Variables

Variable	Theoretical Range	Minimum	Maximum	Mean	SD
Classroom Predictor Variables					
Classrooms (n = 17)					
General Classroom Environment Quality	0 – 5.0	3.17	4.50	3.71	.45
General Cognitive Support	0 – 5.0	1.87	4.42	3.15	.68
Curriculum Fidelity	0 – 5.0	3.04	4.88	4.21	.49
Curriculum Depth (Classroom Average)	0 – 423.0	135.56	258.80	187.41	42.53
Number of Activities (Classroom Average)	0 – 141.0	58.11	110.21	84.00	16.21
Teacher Belief Score for Academics	0 – 1.0	.71	.94	.84	.07
Teacher Belief Score for Mathematics	0 – 1.0	.64	.96	.80	.09
Teacher Education	1.0 – 3.0	1.00	3.00	2.12	.49
Child Variables					
Children (n = 205)					
Math Development	-36.0 – 36.0	-10.00	25.00	8.18	5.52
Curriculum Depth (Individual)	0 – 423.0	37.00	370.00	189.58	76.25
Number of Activities (Individual)	0 – 141.0	36.00	146.00	84.23	23.41

### Correlational Analyses

Bivariate correlations were conducted to determine associations between the classroom-level predictor variables. Several statistically significant findings emerged. The two variables measuring curriculum intensity (i.e., classroom average depth of coverage and classroom average number of activities) were correlated,  $r = .86$ ,  $p < .001$ , as were teachers' fidelity of implementation and the classroom average for depth of curriculum coverage,  $r = .56$ ,  $p = .02$ . Teachers' beliefs about mathematics were correlated with their beliefs about academics, in general,  $r = .65$ ,  $p = .01$ . Further, their beliefs about academics and their level of education were correlated with the general quality of the classroom environment,  $r = .63$ ,  $p < .001$  and  $r = .59$ ,  $p = .01$ , respectively. Finally, teachers' beliefs about mathematics were correlated with their levels of education,  $r = .49$ ,  $p = .05$ , while the relationship between beliefs about academics and levels of education approached significance at  $r = .42$ ,  $p = .10$ . The correlation coefficients for these classroom-level independent variables are displayed in Table 4.

Table 4  
Correlation Matrix for Classroom-Level Independent Variables

Variable	1	2	3	4	5	6	7	8
Classrooms (n = 17)								
1. General Environmental Quality	----	.35	.22	.11	-.19	.63**	.21	.59*
2. General Cognitive Support		----	-.22	.07	-.02	.17	-.02	.00
3. Curriculum Fidelity			----	.56*	.32	.47	-.05	.09
4. Average Curriculum Depth				----	.86**	.08	-.26	-.07
5. Average Number of Activities					----	-.31	-.48	-.26
6. Teacher Belief Score – Academics						----	.65**	.42
7. Teacher Belief Score – Math							----	.49*
8. Teacher Education								----

\*\*  $p < 0.01$ . \*  $p < 0.05$ .

At the child-level, correlational analyses were also conducted to determine the associations among the outcome measure (i.e., mathematical development) and predictor variables: individual values for curriculum depth and number of activities, time interval between pre- and post-test, pre-test score and age at pre-test. Several notable findings emerged. (Note: p-values are not relevant here and are therefore not reported due to the non-independence of the nested data.) Results indicate that pre- to post-test mathematical development gains were

correlated with the depth of the curriculum,  $r = .27$ , and the number of activities completed,  $r = .21$ . Mathematical development was also correlated with testing time interval,  $r = .16$ . Curriculum depth was correlated with the number of curricular activities,  $r = .87$ , and with knowledge at pre-test,  $r = .32$ , and age at pre-test,  $r = .22$ . Knowledge at pre-test was correlated with the number of curricular activities experienced,  $r = .24$ , and pre-test score and pre-test age were also correlated,  $r = .44$ . Neither pre-test score, nor age, were correlated with mathematical development, however. These results are displayed in Table 5.

Table 5  
Correlation Matrix for Child-Level Independent and Dependent Variables

Variable	1	2	3	4	5	6
	Children (n = 205)					
1. Mathematical Development	----	.27	.21	.16	-.11	.06
2. Individual Curriculum Depth		----	.87	-.03	.32	.22
3. Individual Number of Activities			----	-.05	.24	.12
4. Testing Time Interval				----	.14	.05
5. Pre-Test Score					----	.44
6. Age						----

Independent samples t-tests were also conducted to determine whether gender and ELL status were significantly associated with the other independent or dependent variables. No significant effects were found. Chi-square analyses revealed, however, that the percentage of children reporting ELL status significantly varied by gender,  $\chi^2(1, N = 205) = 6.41, p < .05$ , indicating that males were more likely to be ELL students than were females.

#### Relationship among General Classroom Quality, General Cognitive Practices, and Specific Instruction in Mathematics

This section will address the first research question by discussing the relationship among classroom quality variables. Correlational analyses were conducted to determine the associations between the following variables: general environmental quality, general cognitive support, curriculum fidelity, and curriculum intensity as measured by both curricular depth and the number of activities implemented. Two significant correlations emerged. The curriculum intensity variables, depth of coverage and number of activities, were significantly correlated,  $r = .86, p < .001$ . Curriculum fidelity, or the accuracy with which teachers implemented the curriculum, was correlated with depth of curriculum coverage,  $r = .56, p = .02$ , but not with the number of curricular activities completed. The correlation coefficients for these classroom-level independent variables are displayed in Table 4.



Due to the high correlation between curriculum depth and number of activities delivered, in all subsequent analyses, curriculum depth, alone, was used to represent the curriculum intensity variable. Curriculum depth was more highly correlated with mathematical development than was the number of activities delivered, and it was also significantly correlated with another important implementation feature, curriculum fidelity. Furthermore, depth was a more informative measure of curriculum intensity, as it took into account both the number of activities a child was exposed to, as well as their demonstrated levels of understanding for each curricular task.

#### Influence of General Cognitive Practices and Specific Instruction in Mathematics on Mathematical Development

Hierarchical linear modeling (HLM) analyses (Bryk & Raudenbush, 1987) were used to examine the effects of individual and classroom-level variables on children's mathematical development over the preschool year. Multilevel models were used in order to account for the contextual influences of varying classroom environments, with individual children viewed as nested within classroom units. Due to shared experiences, children within the same classroom are often more similar than children across classrooms, and HLM techniques take into account the non-independence of these observations by considering the variability that exists at both the child- and the classroom-levels.

In the subsequent analyses, children's individual curriculum depth scores and teacher variables, such as general classroom quality and cognitive practices, were used to explain the variation in children's pre- to post-test mathematical score gains. Children's time interval between tests was controlled for, as this variable was correlated with mathematical score gains.

As is appropriate when using HLM, the underlying distributional assumptions were evaluated. Both the predictor and outcome variables were normally distributed. Child- and classroom-level residuals were also normally distributed and displayed a linear relationship.

The first set of models addressed the study's second research question: controlling for general classroom quality, do general cognitive practices and specific instruction in mathematics predict children's mathematical development? Models for three independent predictor variables were examined: general cognitive practices, curriculum depth, and curriculum fidelity.

The first model represented the general cognitive practice model. The general cognitive practices variable was measured for each classroom and was, therefore, entered as a predictor at the classroom-level. Children's pre- to post-test mathematical gains were entered as the outcome variable. In this model, holding the testing time interval and general classroom quality constant, cognitive support was not significant at the 0.05 level, ( $\beta = .57, p = .38$ ).

The second model represented the specific instruction in mathematics intensity model, with depth of curriculum as the predictor variable. Depth of curriculum was measured for each student and was, therefore, entered as a predictor at the child-level. Children's pre- to post-test mathematical gains were entered as the outcome variable. In this model, holding the testing time interval and general classroom quality constant, depth of curriculum significantly affected children's mathematical score gains, ( $\beta = .02, p < .001$ ). These results indicate that, for every unit increase in curriculum depth, children gained .02 points in their pre- to post-test mathematical change scores. In practical terms, this means that children must be exposed to and demonstrate mastery in about 17 activities (out of 141 possible) to gain one point (out of 36 possible) on the outcome measure. Although individual activities were as basic as counting to two or counting to three, this suggests that frequent curricular exposure is required to achieve gains, as measured by the DSC.

Finally, the third model represented the specific instruction in mathematics fidelity model, with teachers' curriculum fidelity scores used as the predictor variable. The curriculum fidelity variable was measured for each classroom and was, therefore, entered as a predictor at the classroom-level. Children's pre- to post-test mathematical gains were entered as the outcome variable. In this model, holding the testing time interval and general classroom quality constant, curriculum fidelity was not significant at the 0.05 level, ( $\beta = .98$ ,  $p = .29$ ).

The models and coefficient values are displayed in Table 6.

Table 6  
Effects of General Cognitive Practices and Specific Instruction in Mathematics

Variable	Model 1	Model 2	Model 3
Regression Coefficients			
Intercept	8.19**	8.29**	8.15**
General Classroom Quality	.19	.63	.26
Testing Time Interval	.03*	.02	.03*
General Cognitive Support	.57	--	--
Curriculum Depth	--	.02**	--
Curriculum Fidelity	--	--	.98
Variances			
Between Teachers	.13	.16	.12
Within Teachers	.87	.84	.88

\*\*  $p < 0.01$ . \*  $p < 0.05$ .

#### Independent Contribution of Specific Instruction in Mathematics

The following model, Model 4, addressed the third research question: what is the independent contribution of specific instruction in mathematics after general cognitive practices have been taken into account? Of the two specific instruction in mathematics variables (i.e., curriculum depth and curriculum fidelity), only curriculum depth was a significant predictor of children's mathematical development. Therefore, a single model was used to examine the influence of curriculum depth on children's mathematical gain scores when the effects of general cognitive practices have been taken into account.

Depth of curriculum was measured for each student and was, therefore, entered as a predictor at the child-level. Children's pre- to post-test mathematical gains were entered as the outcome variable. In this model, holding the testing time interval, general classroom quality constant, and cognitive support constant, depth of curriculum significantly affected children's mathematical score gains, ( $\beta = .02$ ,  $p < .001$ ). The effects of curriculum depth remained unchanged after controlling for cognitive support. That is, for every unit increase in curriculum depth, children gained .02 points in their pre- to post-test mathematical change scores. The values of the model's variable coefficients remained largely unchanged after introducing the cognitive practices control, indicating that the effects of curriculum intensity depth are largely

independent from the influence of teachers' general cognitive support practices and that this classroom feature does not significantly affect mathematical development at the individual-level.

Model 4 and its coefficient values are displayed in Table 7. Model 4 is compared to Model 2, the original model, which considers the effects of curriculum depth on children's mathematical gain scores, controlling only for general classroom quality and testing time interval.

#### General Cognitive Practices as a Potential Moderator on the Influence of Specific Instruction in Mathematics on Mathematical Development

The next model, Model 5, addressed the fourth research question: do general cognitive practices moderate the effect of specific instruction in mathematics on children's mathematics development? As in the previous analyses, a single model was examined using the curriculum depth variable as the predictor variable.

Depth of curriculum was entered as a predictor at the child-level. Children's pre- to post-test mathematical gains were entered as the outcome variable. In this model, holding the testing time interval and general classroom quality constant, and treating cognitive support as a moderator, depth of curriculum significantly affected children's mathematical score gains, ( $\beta = .02$ ,  $p < .001$ ). Again, the effects of curriculum depth remained unchanged after controlling for cognitive support. That is, for every unit increase in curriculum depth, children gained .02 points in their pre- to post-test mathematical change scores. The values of the model's variable coefficients remained largely unchanged after introducing the cognitive practices moderator, indicating that the effects of curriculum intensity depth are not influenced by the level of general cognitive support provided in the classroom.

Model 5 and its coefficient values are displayed in Table 7. However, due to the non-significance of the interaction term in Model 5, the coefficients in Model 4 should continue to be used for interpretive purposes.

Table 7  
Effects of Curriculum Depth with Cognitive Practices Considered

Variable	Model 2	Model 4	Model 5
Regression Coefficients			
Intercept	8.29**	8.32**	8.30**
General Classroom Quality	.63	.22	.14
Testing Time Interval	.02	.02	.02
General Cognitive Support	--	.76	-.11
Curriculum Depth	.02**	.02**	.02**
General Cognitive Support x Curriculum Depth	--	--	.00
Variances			
Between Teachers	.16	.14	.14
Within Teachers	.84	.86	.86

\*\*  $p < 0.01$ . \*  $p < 0.05$ .

#### Relationship between Teacher Beliefs, General Cognitive Practices, and Specific Instruction in Mathematics

Although instructional quality, measured generally at the classroom-level, did not significantly predict individual children's mathematical development, the final analyses attempted to add to the literature on preschool mathematics by exploring the relationship between teachers' beliefs and their instructional practices. To further understand the varying levels of general cognitive practices and specific instruction in mathematics across classrooms, their relationships to teachers' beliefs about the role of academics, generally, and mathematics, specifically, were examined. These final analyses used linear regression analyses to determine whether teacher beliefs about academics or mathematics predicted their scores on general cognitive practices, curriculum depth, and curriculum fidelity.

In this sample, teachers' beliefs displayed weak associations with their instructional practices. A trend appeared in the relationship between teachers' academic beliefs and their curriculum fidelity scores. Academic beliefs predicted fidelity scores,  $\beta = 3.25$ ,  $t(15) = 2.04$ ,  $p = .06$ , approaching significance at the  $p = .05$  level. Teachers who believed more strongly in the developmental appropriateness of preschool instruction in language, literacy, and mathematics tended to implement the mathematics curriculum with greater accuracy. Academic beliefs explained 17% of the variance in fidelity scores,  $R^2 = .17$ ,  $F(1, 15) = 4.17$ ,  $p = .06$ , which is notable considering the correlation between implementation fidelity and average curriculum depth scores,  $r = .56$ ,  $p = .02$ . Fidelity scores, however, were not significantly associated with children's pre- to post-test mathematical gain scores. Surprisingly, mathematical belief scores did not predict curriculum depth or curriculum fidelity scores, and academic belief scores did not predict levels of general cognitive practices.

#### Influence of Age, Existing Mathematical Knowledge, and English Language Learner Status on Curricular Experiences and Mathematical Development

For the final set of analyses, HLM was used to determine how child-specific attributes affected individual children's curriculum depth scores and their mathematical development during the preschool year.

In the first analysis, child-level predictors were curriculum depth, pre-test age, initial mathematical knowledge, ELL status, and testing time interval. Children's pre- to post-test mathematical gains were entered as the outcome variable. The overall model significantly predicted children's mathematical gain scores from pre-test to post-test. Existing math knowledge ( $\beta = -.25, p < .001$ ), curriculum depth ( $\beta = .03, p < .001$ ), and testing time interval ( $\beta = .02, p = .01$ ) were significant predictors of mathematical development, while controlling for age and ELL status. These findings are consistent with the previous analyses.

A second analysis was conducted in order to determine whether children's age, initial mathematical knowledge, or ELL status predicted curriculum depth. Age, existing mathematical knowledge, and ELL status were entered as predictors at the child-level. Curriculum depth (individual values) was entered as the outcome variable. The overall model was significant. Results indicated that pre-test score ( $\beta = 3.36, p < .001$ ) and ELL status ( $\beta = -26.40, p = .04$ ) significantly predicted individual children's curriculum depth scores. These results indicate that for every one point in increase in pre-test score, children experienced 3.36 units more curriculum intensity, or approximately one completed and mastered activity, throughout the year. Additionally, children who primarily spoke English at home experienced significantly less intense mathematical curricula than did those who primarily spoke a foreign language at home.

These final two models and their coefficient values are displayed in Table 8.

Table 8  
Influence of Age, Existing Math Knowledge, and ELL Status on Curriculum Depth and Math Development

Variable	Model 6 – Math Development	Model 7 – Curriculum Depth
Regression Coefficients		
Intercept	-6.87**	165.20**
Age	.08	.98
Existing Math Knowledge	-.25**	3.36**
ELL Status	.94	-26.40*
Curriculum Depth	.03**	--
Testing Time Interval	.02*	--
Variances		
Between Teachers	.16	.11
Within Teachers	.84	.89

\*\*  $p < 0.01$ . \*  $p < 0.05$ .

Further inspection of the data revealed that, as groups, ELL and English speaking children did not significantly differ in their mathematical knowledge at pre-test or in their mathematical gain scores across the preschool year. However, when the ELL sample was examined in terms of its two primary subgroups, clear differences emerged between the mathematical experiences of children of Asian and Pacific Islander descent, who accounted for 47% and 43% of the ELL sample, respectively. Children of Asian descent outperformed their ELL peers both at pre-test,  $t(42) = -2.07$ ,  $p = .05$ , in the depth of curriculum received,  $t(40) = -2.76$ ,  $p = .01$ , and in the mathematical gains made across the preschool year,  $t(42) = -3.02$ ,  $p = .00$ . These data indicate that, although the ELL sample, as a whole, appeared to excel in their curricular experiences, there were significant differences by ethnic group in terms of children's initial mathematical knowledge, their classroom experiences, and their subsequent mathematical development. These trends were notable in this sample, as Asian American ELL children were enrolled across 9 of the 17 classrooms.

Asian American ELL children did not only outperform their ELL peers; they also outperformed their English speaking peers. ELL children of Asian descent received significantly more intense mathematics curricula,  $t(177) = 3.37$ ,  $p = .00$ , and made significantly greater mathematical knowledge gains,  $t(177) = 2.03$ ,  $p = .04$ , than did English speaking children. There were no significant differences in pre-test scores between these groups, however.

## CHAPTER 5. DISCUSSION

This chapter will present a summary of the research questions and findings, followed by a discussion of the results. Areas for future research and implications for educational policy and practice will also be discussed.

### Summary

The purpose of this study was to determine how general and mathematics-specific classroom instructional quality influenced a sample of Head Start children's mathematical development during the preschool year. The study also examined whether children's age, pre-test mathematical knowledge, and English language learner status influenced the quality of their curricular experiences and subsequent mathematical development.

The first research question asked: to what extent are general classroom quality, general cognitive practices, and specific instruction in mathematics related to each other? Levels of general environmental quality, general cognitive practices, and the quality of mathematical instruction were found to be statistically unrelated. Only measures of mathematics instruction, specifically curriculum intensity and fidelity, were significantly correlated.

The second research question asked: controlling for general classroom quality, do general cognitive practices and specific instruction in mathematics predict children's mathematical development? Contrary to expectations, general levels of classroom cognitive support did not predict differences in children's pre- to post-test mathematical knowledge scores. Although the quality of cognitive support did not predict children's mathematical development, the intensity of an individualized mathematics curriculum significantly explained variations in children's pre- to post-test mathematical achievement scores. Children who received the most intensive curricular experiences made the most pre- to post-test gains on a test of mathematical knowledge. Further, children with higher pre-test scores received more intense curricular experiences, although they did not typically make greater mathematical gains than children beginning the year with lower pre-test scores.

The third research question assessed whether or not specific instruction in mathematics influenced children's mathematical gains after general cognitive practices were taken into account. Because general levels of cognitive support, independently, did not predict children's mathematical development, they also did not affect the relationship between curriculum intensity and children's mathematical development. Curriculum intensity remained a significant predictor of children's pre- to post-test mathematical knowledge gains.

The fourth research question asked: Do general cognitive practices moderate the effect of specific instruction in mathematics on children's mathematics development? The interaction between general cognitive practices and curriculum intensity was also found to be statistically insignificant, with curriculum intensity, alone, remaining a significant predictor of mathematical development across the preschool year.

The final question investigated the influence of age, existing mathematical knowledge, and English language learner status on children's curricular experiences and mathematical development. The influence of ELL status, particularly for children of Asian descent, was significant. Although children did not significantly differ in mathematical knowledge at pre-test, Asian-American ELL children experienced greater curriculum intensity and made greater mathematical gains from pre-test to post test than their predominantly English speaking peers. Asian American ELL children also outperformed their Pacific Islander ELL peers at pre-test, in the intensity of their curriculum experiences, and in their overall mathematical development across the preschool year.

## Discussion

Over the past twenty years, developmental and educational researchers have revealed a wealth of knowledge about young children's early mathematical competencies (e.g., Bialystock & Codd, 2000; Cooper, 1984; Fuson, 1988; Wynn, 1998) and identified mathematical domains and learning goals for young children (NAEYC, 2005; NAEYC & NCTM, 2002; NCTM, 2000). Still left to investigate, however, are specific models for the development of children's mathematical thinking (Pianta, 2008) and specific curricular implementation features and instructional strategies that maximize children's mathematical development during the preschool year (Ginsburg et al., 2008; Golbeck, 2001). In particular, scientists have yet to suggest whether children's mathematical competencies are developed primarily through the use of skill-building curricular activities, or whether additional cognitive supports, such as those that develop higher order thinking skills, are also necessary. This study is a modest first step in addressing these important questions.

The findings revealed that variations in curriculum implementation significantly influence children's mathematical development. Children who receive more intense curricular experiences, as measured by the number of completed activities as well as levels of demonstrated understanding, make greater mathematical gains than do those who receive less intense experiences. Although the quality of general cognitive support provided in the classroom did not predict children's mathematical development in this study, additional research is necessary to completely rule out the influence of instructional support for higher order thinking skills.

These findings add to the literature on early childhood mathematics in two important ways. First, they suggest that the intensity of individual children's mathematical experiences is predictive of their mathematical gains across the preschool year, providing further support for recent efforts to increase the presence of mathematical activity in early childhood settings (NAEYC & NCTM, 2002; NCTM, 2000). Second, because the quality of mathematics instruction and children's mathematical development were unrelated to general classroom and instructional quality, these results suggest that mathematics may be a content area and instructional process distinct from the general instructional interactions occurring in the preschool classroom. This provides further support for the call for the development of research-based validated instruments that specifically measure the quality, quantity, and conceptual depth of teachers' mathematical interactions (Ginsburg et al., 2005; Ginsburg et al., 2008; Sarama et al., 2004). These would enable more accurate study of the relationship between the quality of mathematical instruction, including teachers' support for mathematical higher order thinking skills, and children's developmental outcomes in early childhood settings.

### Affirming the Relevance of Early Childhood Mathematics

A groundbreaking effort in the field of early childhood mathematics occurred just nine years ago, in the year 2000, at the Conference on Standards for Prekindergarten and Kindergarten Mathematics Education. For the first time, researchers, practitioners, and policy makers met in a collaborative effort to establish early childhood mathematics standards, curricula, and teaching strategies (Clements, Sarama, & DiBiase, 2003). Mathematics is truly a new endeavor in our preschools, and despite its importance and implications for children's later mathematical skill acquisition, overall educational attainment, and future job prospects (Geary, 2000), it is not yet a standard component of typical early childhood settings.

This study adds further support to the field's call for an increased presence of mathematics in the preschool classroom (NAEYC & NCTM, 2002; NCTM, 2000). As expected, preschool children who received more frequent mathematical activities, and who persisted with the activities until they demonstrated more than a basic understanding of the relevant



mathematical concepts, advanced their knowledge more than did those children who received and demonstrated less. These findings suggest that more time and attention should be devoted to mathematics instruction and to individualized curricula for preschool children. Preschool teachers typically spend just 15% of morning class time on math and science instruction combined (Layzer et al., 1993), often merely in the context of daily routines (Lee & Ginsburg, 2007a). Although children naturally will learn about mathematics through their everyday life experiences, teachers are essential for guiding mathematical activities toward appropriate learning goals, cultivating higher order thinking skills, focusing children's attention on the relevant mathematical ideas, correcting misinformation, and transforming children's everyday mathematical knowledge into theoretical, scientific concepts. Even today, mathematics instruction requires a more prominent role in early childhood settings; it is as essential as literacy.

The weak support that mathematics receives in many preschool classrooms is not surprising due to teachers' lack of preparation and confidence in teaching the subject. Typically, while teacher preparation programs offer multiple literacy course offerings, they may offer as few as one course in general, not preschool, mathematics (Copley, 2004; Ginsburg et al., 2005). As a result, not only do many early childhood educators express concern over their ability to support mathematics in their classrooms, but they also tend to narrowly conceptualize mathematics as limited to numbers and shapes (Copley, 2004; Farran, Silveri, & Culp, 1991). Despite these limitations, the field must continue to advocate for and develop strategies for supporting teachers in their efforts to deliver mathematical experiences, of sufficient depth and breadth, to children in early childhood settings.

Although this study identified the significant influence of curricular intensity, further study of the effects of curricular individualization on children's mathematical development is warranted. In theory, curriculum individualization encourages both curricular depth and breadth and provides repeated opportunities for children to master the relevant mathematical concepts. Curricular individualization, however, is a time consuming and challenging task for preschool teachers. Therefore, it is essential to identify whether or not an individualized curriculum benefits children's mathematical development above and beyond the influences derived from their basic experience with the curriculum, in the first place. Subsequent curriculum studies should examine whether there are significant differences in mathematical development when children receive individualized mathematical instruction versus a common pacing and sequence of mathematical activities for all. This would pinpoint the exact benefit, if any, of curricular individualization, and would broaden the field's understandings about the essential components of preschool mathematics education.

#### Distinct Patterns of Instructional Quality

Although mathematics deserves a place among the other necessary elements of early childhood settings, including literacy, language promotion, and a rich physical environment, it is a content area that must be studied and evaluated independently. The finding that the quality of mathematical instruction and children's mathematical development were unrelated to general classroom and instructional quality suggests that mathematics may be a content area and instructional process distinct from the general instructional interactions occurring in the preschool classroom. As expected, there were weak relationships among the various types of classroom quality, suggesting that a teacher may not demonstrate strengths consistently in all aspects of their instruction. This is consistent with previous studies, which have found that teachers may demonstrate high classroom quality in a global sense, yet may actually provide low

quality mathematical instruction and support (e.g., Frede et al., 2007). For example, teachers who created classroom environments high in physical (e.g., safe, stocked with materials) and interactional (e.g., good use of discipline) quality were not necessarily employing high quality intellectual support strategies or implementing mathematics curricula in an optimal manner. Therefore, while general classroom quality may reveal important information about basic levels of environmental adequacy, it likely reveals little about the quality of teachers' learning environments or the specific instructional interactions (Loeb et al., 2004) that may be more directly related to mathematical learning.

The study also found no significant relationship between the quality of teachers' mathematical curriculum and their support for general thinking skills, although teachers' beliefs about the developmental appropriateness of mathematics and academics, in general, were correlated. This finding was in contrast to the expectation that teachers who implement the mathematics curriculum with high levels of accuracy and intensity are likely to also provide high levels of support for general thinking skills, since both instructional elements may be related to teachers' pedagogical orientations toward supporting academics in preschool. As mentioned previously, however, due to a lack of training and the recent onset of the preschool mathematics movement, many early childhood educators are unprepared to support children's mathematical development and express discomfort over teaching it (e.g., Copley, 2004). Mathematics may not yet be a standard, integral part of the preschool experience, and, hence, teachers' beliefs about and support for mathematics may not overlap with the broader category of support for academics in preschool. This may partially explain the lack of association between teachers' support for general academics and their support for mathematics, specifically.

The discrepancy in findings, however, may also be due to the ways in which the constructs were measured. Curriculum quality was measured in the context of mathematics activities only, while general cognitive practices were measured across a variety of experiences throughout the day, not all of which were directly related to structured learning activities. Levels of cognitive support provided during circle time or small group activities likely vary from those provided during transitions or daily care activities, such as tooth brushing. Thus, while mathematical curriculum quality was measured in the context of academic learning experiences only, teachers' support for general cognitive development was measured across both academic and routine classroom activities. The discrepancy in measurement contexts may have been problematic for addressing the research questions in this study. For example, it may be that, despite Underbakke et al.'s (1993) suggestion that critical thinking skills develop independently from specific instructional content, cognitive support provided in general classroom interactions may not influence mathematical development to the same extent that cognitive support provided in mathematics-specific interactions does. This is further supported by the finding that high quality general cognitive instruction did not predict children's mathematical development.

These findings are contrary to expectations, as research suggests that mathematical development requires both the instruction of general thinking skills, such as problem solving and communication, and specific curricular content (NCTM, 2000; Resnick, 1989). Previous research also indicates that high levels of general cognitive support promote deep conceptual understandings and approaches to learning (Crooks, 1988) and improve task performance (Bohlmann and Fenson, 2005), although it seemed to have little effect in the mathematical development of the children in this study.

To more adequately investigate the relationship between cognitive support and children's mathematical development, subsequent studies should be sure to evaluate cognitive support practices in the context of mathematical, not general, classroom activities.

An additional explanation for these unexpected findings may be the limited and artificially homogenous study sample size. All 17 classrooms and their teachers were self-selected project volunteers, who likely shared common beliefs about the importance of supporting academic preparedness in preschool. Without sufficient variability in demonstrated levels of cognitive support, as was evidenced here by the fact that classrooms, on average, rated above national averages on levels of cognitive support (La Paro et al., 2004), it is difficult to adequately address the influence of the construct on children's developmental outcomes.

Together, these findings reveal the need for ongoing refinement of the literature on classroom quality, specifically that of the mathematical quality of early childhood settings.

One necessary addition to the classroom quality literature would be a reliable and valid instrument which specifically measures the quality of the mathematical learning environment, as no such instrument currently exists (Ginsburg et al., 2006; Ginsburg et al., 2008; Sarama et al., 2004). The development of such an instrument would benefit the field in two ways: (a) further study of the instructional components of mathematical interactions (e.g., intensity of curriculum, quality of feedback during instruction) would enable more precise investigation of the relationship between teaching quality and children's mathematical development and (b) teachers would be better able to assess and track the quality of the mathematical support provided to young child in their care. Such an instrument would have the advantage of measuring the quality of cognitive support processes during mathematics-specific activity. This would enable researchers to identify the particular instructional strategies that optimally support mathematical development in the early childhood setting. Such findings may help researchers understand the ways in which early mathematical knowledge develops and the cognitive capacities underlying its development.

Adding further support to the proposition that mathematics may be a content area distinct from other aspects of the early childhood curriculum is the finding that, as predicted, the two aspects of teachers' mathematical instructional quality were related. Specifically, the quality of teachers' curricular intensity and fidelity were significantly correlated. This reveals that teachers who were more faithful to curriculum implementation instructions were more likely to achieve higher levels of curricular intensity with their students. While implementation intensity was a significant predictor of mathematical development, implementation fidelity was not. Teachers in this study, however, all performed relatively well on measures of curriculum fidelity throughout the year. This finding suggests that, when teachers consistently demonstrate medium to high levels of implementation fidelity, future curriculum research projects should reconsider the necessity of ongoing fidelity monitoring. Perhaps time and financial resources may be better spent monitoring the intensity of curricular experiences delivered to children in the classrooms, which is more directly associated with improvements in student learning.

#### Influence of the Child's Pre-Test Knowledge and ELL Status

Despite their best efforts, teachers' instructional patterns are only one influential aspect of a child's early mathematical experience. Children bring to their classroom a number of influential attributes, including variations in previous mathematical experience and language status, and these characteristics influence children's subsequent learning experiences. In this study, as expected, child characteristics influenced individual levels of curricular intensity and

subsequent mathematical development. Children's mathematical knowledge at pre-test and their ELL status accounted for 12% of the explained variance in children's intensity scores.

Children who entered preschool with more mathematical knowledge experienced more intense curricular experiences. This suggests that the attempt at curricular individualization was partially successful; the children who started ahead remained ahead and did not completely "fall back" to the knowledge levels of their peers by the end of preschool. This finding further reinforces the importance of the home environment and suggests that children could potentially make greater gains in preschool if they entered with a basic familiarity with mathematics, such as knowledge of shape names or simple counting.

Furthermore, as predicted, the influence of ELL status was significant, although its positive association with more optimal mathematical outcomes was contrary to expectations. In particular, Asian-American ELL children experienced greater curriculum intensity and made greater mathematical gains from pre-test to post-test than both their ELL and predominantly English speaking peers. One theory for this advantage is the greater mathematical experiences that Asian children may receive at home. Research reveals that Asian children outperform American students on tests of mathematical achievement as early as first grade (Stigler, Lee, & Stevenson, 1990), and this is likely due to their greater mathematical preparedness in early childhood (Ginsburg et al., 1997).

In a study of Chinese-American, Taiwan-Chinese, and second-generation Euro-American preschool and kindergarten-aged children and their families, Huntsinger et al. (1997) found that Chinese-American parents displayed more formal patterns of mathematics instruction than did Euro-American parents. Specifically, Chinese-American parents were more directly involved in teaching mathematics, structured their children's mathematical activity time to a greater degree, and were more likely to encourage their children's engagement in mathematical activities. The Chinese-American and Taiwan-Chinese children also demonstrated greater mathematical knowledge on tests of mathematics, spatial relations, and numeral formation. These findings suggest that Asian families likely provide greater support for their young children's mathematical development in the home environment when compared to their American peers, a fact which likely contributes to their superior performance on assessments of mathematical knowledge.

Another possible explanation for the advanced performance of the Asian American ELL children is that of the home language. Unlike the English language, Asian languages employ regular, predictable number-naming systems, and this has been suggested as one explanation for the better performance of Asian children on tests of mathematical ability (Miller, Smith, Zhu, & Zhang, 1995; Miura et al., 1994). For example, while the English number system is unstructured and must be learned by rote (e.g., ...nine, ten, eleven..., ...nineteen, twenty, twenty-one...), number systems are patterned and predictable in many Asian languages (e.g., ...nine, ten, ten-one..., ...ten-nine, two ten, two ten-one...). This may contribute to Asian children's superior fluency with counting and the manipulation of numbers. It is reasonable to assume that the Asian American ELL children in this sample were exposed to this patterned number system structure, as the criteria for ELL classification was the predominance of a foreign language spoken in the home, and this may also contribute to their greater success with preschool mathematics.

Finally, differences in the beliefs about the nature of intelligence as either fixed or malleable may also explain Asian American ELL children's patterns of increased curriculum intensity and greater mathematical gains as compared to their English speaking peers. These

advantages are particularly remarkable considering that these children began preschool with the same level of mathematical knowledge. In a study of mathematics achievement in the USA, Japan, and China, Stevenson and Lee (1990) found there to be fundamental differences between American and Asian cultures in their beliefs about the nature of achievement. While American families tended to express general satisfaction with their children's achievement and attribute it to natural ability, Asian parents were more growth-oriented and expressed greater appreciation for the positive benefits of effort and hard work. In fact, Japanese and Chinese parents believed that effort contributed to success even more than did innate ability. This is in contrast to American parents, who underplayed the effects of children's efforts and were generally more satisfied with their children's current levels of mathematical achievement, despite the fact that they were outperformed by their Asian counterparts. These findings suggest that the Asian American ELL children in this study may have benefited from greater parental support for their efforts to master their preschool mathematics curriculum, which may have led to their superior performance throughout the year and at post-test.

Although the Asian American ELL children in this study were American, considering that their primary language at home was an Asian language, it is reasonable to conclude that Asian culture may still pervade children's home experiences. It is possible that once the Asian American ELL children began preschool and were introduced to structured mathematical learning experiences, parents supported these activities at home and encouraged their children's engagement with and mastery of the material to a greater extent than other project parents. Teachers, in turn, likely adjusted their instruction to advance these children onto more challenging activities and a more intense curricular experience. Together, the advantages at home and the resulting advantages in the classroom may have led to the group's greater mathematical progress during the preschool year.

These findings reinforce the importance of children's early, out-of-school experiences with mathematics. In this study, when an individualized curriculum was provided at school, these background factors accounted for 8% of the variation in children's mathematical gain scores. The findings also suggest a need for further study of the experiences of Asian American ELL students. Although several theories have been proposed for their relative advantage in mathematics, it is important to identify specifically what is happening at home or in the classroom to contribute to their advantages in curricular intensity and mathematical gains from pre- to post-test. If particular methods of parental support are found to be advantageous, these findings may have significant implications for developing more effective parent outreach in preschool programs serving low-income children.

#### Limitations

This study was limited in several ways. First, only 17 classrooms were included, a rather small sample size for analyzing the effects of classroom-level variables on children's developmental outcomes. Considering the importance of determining how teachers' instructional interactions influence the efficacy of curricula and children's development, large scale studies examining classroom-level variations and their effects on mathematical development are warranted to meet optimal conditions for multi-level modeling.

The relative homogeneity of the sample also limited the study's findings. Teachers participating in this curriculum study constituted a self-selected sample of volunteers. As a group, they likely support the inclusion of structured mathematical learning experiences in early education settings to a greater degree than teachers in general preschool populations, particularly on account of their association with Head Start. Research has found that teachers of low-income

children express a stronger appreciation for mathematics and more often recognize their role in facilitating this type of learning (Lee & Ginsburg, 2007a) than do teachers of middle-SES children. Furthermore, by virtue of their participation in the curriculum project, teachers received similar professional development experiences. These limitations were apparent in the fact that teachers' classroom quality scores were consistently at or above national averages (La Paro et al., 2004). Although variations were still observed in instructional quality, curriculum implementation, and beliefs about academics and mathematics, these scores likely under-represent the true variability in these practices in the general population.

The scope of some research measures was also rather limited. For example, the general classroom environmental quality rating was derived from just five item ratings, fidelity measures were completed for only a small subset of mathematics activities, and teacher belief surveys consisted of only 5- and 10-items for mathematics and general academics, respectively. The mathematical outcome measure, DSC, was also limited to 36 items across 10 problem types. There were also no instruments included which directly assess the quality of teacher-child mathematical interactions, as no such measures yet exist. Although all included research measures possessed psychometric properties suitable for use in the study, more extensive and refined measures would be warranted in future studies to capture more subtle variation in classroom- and child-level variables.

Finally, the study sample is not an adequate representation of the American population at large. This study was conducted in Hawai'i, and the sample represents the state's unique multicultural, predominantly Asian and Pacific Islander population. In this study, ethnicity played an interesting role in the evaluation of the effects of ELL status on children's mathematical development. About half of the study's ELL children were of Asian descent and their preschool experiences were relatively advantaged as compared to that of their peers. In light of language and cultural differences, ELL children in America often face challenges adapting to the classroom environment; the ELL advantage observed in this study is not likely representative of the experiences of most ELL children in America. Therefore, the study's findings about the effects of ELL status on mathematical experiences and outcomes should not be generalized beyond the specific population included in this sample.

Finally, it is important to note that this study did not attempt to compare participant children's experiences with those of children in control group classrooms. As such, the findings likely underestimate the overall influence of curricular experiences or teachers' instructional quality, as no comparisons were made to more typical preschool experiences, where mathematical instruction is scant (Layzer, Goodson, & Moss, 1993; Lee & Ginsburg, 2007a) and teachers are typically unprepared to adequately support children's mathematical development (Copley, 2004; Copley & Padron, 1999; Farran, Silveri, & Culp, 1991). Previous research has confirmed that children in LC classrooms showed greater gains on performance measures of math skills than children enrolled in classrooms implementing either a teacher-designed curriculum or the Creative Curriculum (DeBaryshe & Gorecki, 2005; Sophian, 2004), with effect sizes ranging from .21 to .81 SD.

#### Implications

This study provides additional support for the preschool mathematics movement, which has demonstrated a dramatic increase in the productivity of its research, practice, and policy-making in a short twenty year time frame. Although the field has made tremendous strides, many questions remain unanswered and much work must still be done before mathematics is embraced as a necessary and developmentally-appropriate content area for preschool, as are

language and literacy. This study reaffirms the importance of curricular intensity in preschool mathematics instruction. It also provides preliminary evidence suggesting that teachers' mathematical instruction may be a distinct early childhood content area, which can not be assumed to be related to the overall quality of the classroom or to teachers' general instructional quality. Teachers must be educated on children's developmental trajectories in early mathematics, and they must be prepared to provide challenging mathematical experiences in a focused, intentional manner. Mathematics should not only appear in the context of other aspects of the early childhood curriculum, such as in cooking demonstrations and art activities, as is too often observed in today's typical preschool settings.

This study's findings have important implications for educational policy and practice. First, the positive effects of curriculum intensity on children's mathematical development suggest that more planned instruction should be included for mathematics in early education settings. Intentional, structured mathematical learning experiences are relatively uncommon in preschool classrooms, and some teachers still consider mathematics a developmentally inappropriate topic for preschool. Preschool programs should adjust classroom schedules and teacher responsibilities to allow for greater instructional time, particularly for one-on-one or small group learning. Furthermore, formative assessments that monitor individual children's development should be included in curricular packages marketed to early childhood educators. Together, these measures will help to promote learning experiences that are sufficiently and appropriately intense for each child's demonstrated level of mathematical understanding.

Improvement to teacher training and professional development programs is also warranted. Teacher education programs should stress the need for mathematical content coverage in preschool settings and should provide greater substantive training in assessing and monitoring individual children's mathematical development. Ongoing professional development to ensure that teachers continually make improvements in the mathematical quality of their instruction is also necessary for both novice and veteran teachers, as mathematics is still a developing content area in early childhood settings. Mathematical professional development is particularly necessary for teachers in publicly funded preschool programs, such as Head Start, which serve our nation's neediest children.

Finally, the positive effects of Asian American ELL status on children's mathematical experiences and development reiterate the importance of assuming an individualized approach to instruction. The finding further reveals that teachers should avoid blanket generalizations about the ELL students they serve. Although all ELL students likely experience language and cultural challenges when adapting to their American school experiences, some groups may exhibit compensatory factors, such as home support for learning, which enable them to flourish when provided sufficiently challenging classroom learning experiences. Teachers should be aware of differences across cultural and ethnic populations, explore the nature of demonstrated family strengths, and strive to serve each child in light of their unique experiences and personal attributes.

### Conclusion

In response to the recent call for "more careful study of effective instructional processes" in mathematics (Pianta, 2008, p. 12), this study explored the influence of classroom instructional quality and specific child characteristics, such as ELL status, on a sample of Head Start children's mathematical development during the preschool year. Although these findings should be considered preliminary and interpreted with caution, the study suggests that the field is right to advocate for the inclusion of early mathematics curricula and research specific to the study of

mathematical quality and instruction in the preschool setting. Early childhood mathematical experiences are both developmentally appropriate and intellectually beneficial to young children, and researchers should continue to refine the field's understanding of the necessary components of an early mathematics education.



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## APPENDIX A: LC CURRICULUM DOMAINS AND LEARNING GOALS

### Language and Literacy

#### **Oral Language**

- To use more diverse and sophisticated vocabulary
- To engage in conversations of increased length and complexity

#### **Phonological and Phonemic awareness**

- To segment and blend compound words and syllables
- To recognize and generate rhymes
- To segment and blend onsets and rimes
- To recognize and generate words with the same initial, final, and medial sounds
- To segment and blend phonemes

#### **Alphabet Knowledge and Print Awareness**

- To recognize and identify letter symbols and letter names
- To identify letter-sound correspondences
- To track print from left to right and top to bottom
- To be aware of the functions of print
- To make use of environmental print
- To use print to convey meaning
- To read C-V-C words

#### **Emergent Writing**

- To use writing to convey meaning
- To strengthen fine motor skills and use tools in preparation for writing
- To use increasingly higher levels of emergent writing
- To use a left-to-right and top-to-bottom orientation when writing
- To begin to spell simple words using letter-sound correspondence

#### **Approaches to Learning**

- To increase attention and persistence when doing LC activities
- To incorporate newly learned skills in free play

### Mathematics

#### **Numbers and Mathematical Operations**

- To understand one-to-one correspondence
- To understand and associate numerals and quantities from 1-10
- To use alternative counting units
- To understand that adding/removing objects increases/decreases total number
- To use composite units and manipulatives to indirectly perform operations (add, subtract, multiply, divide)

#### **Geometry and Spatial Sense**

- To identify basic, advanced, and three-dimensional shapes
- To understand that new shapes can be made by combining two or more shapes
- To identify a given shape within a larger pattern or array
- To compare attributes of objects, e.g., shape, size, color, thickness, number of sides or angles
- To understand spatial relations, e.g., above, below, behind, next to, close, far

#### **Measurement**

- To seriate objects
- To distinguish dimensions of measurement, e.g., height, width, length, volume, area
- To use standard and nonstandard units of measurement
- To use measurement tools, e.g. balance, ruler
- To make and confirm predictions about objects that differ in terms of size, weight, volume, and area

#### **Data Analysis**

- To contribute data points to simple graphs
- To understand simple graphs

#### **Mathematical Conversation**

- To engage in increasingly complex mathematical conversations that incorporate prediction, problem-solving, and definitions
- To use spatial, number, geometry, and measurement terms in spontaneous conversation throughout the day



**APPENDIX B: DATA OVERVIEW FOR MAIN RESEARCH QUESTIONS**

<b>Variable Name</b>	<b>Description</b>	<b>Instruments</b>	<b>Data Type</b>	<b>Data Collectors</b>	<b>Timing of Collection</b>
<b>Outcome Measures</b>					
Math Development	Change in scores from pre- to post-test	DSC	Quantitative	Author and other trained assessors	Fall 2006, 2007 (pre-test) Spring 2007, 2008 (post-test)
<b>Predictor Variables</b>					
General Classroom Environment	Classroom observation	ELLCO	Quantitative	Author and other trained observers	Fall 2006, 2007 Winter 2006, 2007 Spring 2007, 2008
General Cognitive Processes					
Instructional Support -Concept Development -Quality of Feedback -Language Modeling	Classroom observation	CLASS Pre-K	Quantitative	Trained observers	Fall 2006, 2007 Winter 2006, 2007 Spring 2007, 2008
Specific Instruction in Mathematics					
Curriculum Intensity	Depth and breadth of exposure to math curriculum activities	Project-specific curriculum activity logs	Quantitative	Teachers	Throughout the year, as activities are introduced and mastered
Curriculum Fidelity	Accuracy of delivery according to instructions and conceptual goals	Project-specific fidelity measure	Quantitative	Full-time project coaches	Once per month
<b>Control Variables</b>					
Initial Math Knowledge	Child's pre-test score	DSC	Quantitative	Author and other trained assessors	Fall 2006, 2007 (pre-test)
Pre- to Post-Test Time Interval	Time between child's testing sessions	N/A	Quantitative	N/A	N/A
Gender	Male or Female	N/A	Dichotomous	N/A	N/A
Language	English language learner or Not	N/A	Dichotomous	N/A	N/A
Age	Child's age	N/A	Quantitative	N/A	N/A
Teacher Education	Educational level attained: AA, BA, MA	N/A	Quantitative	N/A	N/A

**APPENDIX C: PSYCHOMETRIC PROPERTIES OF PUBLISHED  
PERFORMANCE MEASURES**

	<b>DSC</b>	<b>ELLCO</b>	<b>CLASS Pre-K</b>
Authors	CTB/ McGraw-Hill, 1990	Smith & Dickinson, 2002	Pianta, La Paro & Hamre, 2006
Content	Emergent math	General environment and language/literacy specific curriculum	Quality of instruction & interaction
Norms	Spring preK NCE	N/A	N/A
SEM	2.27	N/A	N/A
Internal consistency	.89	.73-.90	.79-.91
Inter-rater agreement	N/A	88%	87%
Test-retest reliability	N/A	unavailable	.81-.86
Convergent validity	ESA .73	Abbott-Shim .31-.44 Predicts PPVT-III scores	ECERS .33-.63 Predicts child test gains

## APPENDIX D: LEARNING CONNECTIONS MATH ACTIVITY LOG

NUMERATION		1	2	3	4	5	6	7	8	9	10	0	MEASUREMENT ATTRIBUTES							
<b>Counting Objects</b>													Big	Small	Long	Short	Tall			
Eggs and Cartons I													Heavy	Light	Thick	Thin				
Blue and Red Rods													Full	Empty	Almost Full					
<b>Naming Numerals</b>													<b>Seriation</b>							
Numerals Cards													Nuts and Bolts			Cylinder Sort				
<b>Link Num &amp; Quantities</b>													Red & Blue Rod Stairs							
Assoc. of Rods														<b>Measure Lengths</b>	<b>Compare lengths</b>					
Ping Pong Counters													Our Body							
Mystery Game													Broad Jump							
<b>OPERATIONS</b>													Slippers							
Eggs & Marbles I				Eggs & Marbles II									Slipper Strips							
1, 2, 3 Shapes Cards	1	2	3	4	5	6	7							<b>Measure Heavy/Light</b>	<b>Compare Heavy/Light</b>					
Multiplication													Hands							
1, 2, 3 Shapes Cards	8	9	0	1	1	2							Balance							
Addition													<b>Measure Volume</b>	<b>Comparing volume</b>						
<b>GEOMETRY</b>													Filling Containers			Container A, B, C				
<b>Naming shapes (A New Shape)</b>																		Containers A,C		
circle	triangle		trapezoid			hexagon						<b>Comparing Attributes</b>								
square	rectangle		rhombus				parallelogram						Discovering attributes in block corner							
<b>Shape Definitions</b>													Attribute blocks and sorting							
Sorting Shapes														Shapes	Size	Thickness	Color			
<b>Shapes can be made from other shapes</b>													1 Attribute							
Exploration of Pattern Blocks													2 Attribute							
Shapes that Make a Shape I						Shapes that Make a Shape II						Venn Diagram								
Quilt Pattern Designs													<b>Changing Dimensions</b>							

### Instructions

1. One card per child
2. Rate the child's conceptual understanding for each activity completed: introduced, in progress or mastered.
3. Update the rating each time an activity is repeated

- = Introduced
- ◐ = In Progress
- = Mastered

## APPENDIX E: LEARNING CONNECTIONS FIDELITY RATING SCALE

### 1. The environment reflects the activities of the previous and current week.

<b>Overall Set-up of LC Materials:</b> LC Materials are aesthetically prepared and made a part of the everyday classroom		
<b>Poor (1, 2)</b>	<b>In-progress (3)</b>	<b>Mastery (4, 5)</b>
<ul style="list-style-type: none"> <li>• LC Materials are in the teacher's area</li> <li>• LC Materials are in the original packaging</li> <li>• LC Materials are not available to the children during center time</li> </ul>	<ul style="list-style-type: none"> <li>• LC Materials are available in the classroom</li> <li>• LC Materials are clumped together by the activities of the day</li> <li>• LC Materials are placed randomly throughout the classroom</li> <li>• Unrelated materials are displayed with LC Materials</li> </ul>	<ul style="list-style-type: none"> <li>• LC Materials are easily available and accessible in the appropriate center</li> <li>• LC Materials are neatly displayed</li> <li>• LC Materials are organized developmentally on the shelves</li> <li>• Only necessary LC materials are prepared and available on the shelf</li> </ul>

### 2. Quality and effectiveness of curriculum lesson delivery.

<b>Accuracy of Implementation:</b> Teacher implements the lesson in a way that clearly follows the stated goal and steps of the directions		
<b>Poor (1, 2)</b>	<b>In-progress (3)</b>	<b>Mastery (4, 5)</b>
<ul style="list-style-type: none"> <li>• Does not follow directions</li> <li>• Changes the intended goal of the activity</li> </ul>	<ul style="list-style-type: none"> <li>• While presenting activity, may switch between intended goal and own goal</li> <li>• May miss a step or two of the instructions</li> <li>• Materials are incomplete or not prepared</li> </ul>	<ul style="list-style-type: none"> <li>• Uses intended target vocabulary</li> <li>• Uses identified or appropriate materials</li> <li>• Demonstrates activity following the directions</li> <li>• Addresses intended goal of the activity</li> </ul>

<b>Quality of Instruction:</b> Teacher's interaction with the child promotes the development of the target concept		
<b>Poor (1, 2)</b>	<b>In-progress (3)</b>	<b>Mastery (4, 5)</b>
<ul style="list-style-type: none"> <li>• Frequently fails to respond to the child's comments</li> <li>• Little or no evidence of accommodation or scaffolding</li> <li>• Many times conversation detracts from lesson</li> <li>• Questions are primarily low-level</li> </ul>	<ul style="list-style-type: none"> <li>• Engages in minimal feedback or conversation</li> <li>• Some scaffolding to meet child's needs</li> <li>• At times will correct child's mistakes during the lesson</li> <li>• Uses some higher level questions with most being lower level</li> </ul>	<ul style="list-style-type: none"> <li>• Responds to the child's questions or comments</li> <li>• Scaffolds the activity to meet the child's needs</li> <li>• Encourages conversation that supports lesson</li> <li>• Accepts incorrect responses and returns to the concept later</li> <li>• Asks higher level questions</li> </ul>
<b>Choice of activity level:</b> Teacher chooses activity to match child's developmental level		
<b>Poor (1, 2)</b>	<b>In-progress (3)</b>	<b>Mastery (4, 5)</b>
<ul style="list-style-type: none"> <li>• Child lacks prerequisite skills or knowledge to complete the activity as intended</li> <li>• Too many children invited to activity</li> </ul>	<ul style="list-style-type: none"> <li>• Child possesses some prerequisite skills, but struggles with the activity</li> <li>• Child easily completes the activity without difficulty or interest</li> <li>• Too many or too few materials for child's developmental level</li> </ul>	<ul style="list-style-type: none"> <li>• Child has the prerequisite skills to be successful at the activity</li> <li>• Activity challenges the child</li> <li>• Number and type of materials matches the level of the child</li> <li>• Adjusts group size according to the needs of individual children</li> </ul>
<b>Engagement of Children:</b> Children are interested and involved in the activity		
<b>Poor (1, 2)</b>	<b>In-progress (3)</b>	<b>Mastery (4, 5)</b>
<ul style="list-style-type: none"> <li>• Frequently off task and inattentive</li> <li>• Fails to engage in the activity with teacher</li> <li>• Frequently conversation is off topic</li> <li>• Needs constant redirection and encouragement</li> </ul>	<ul style="list-style-type: none"> <li>• Spends more time focused than unfocused</li> <li>• Moderate level of interest and engagement</li> <li>• Makes few relevant comments or questions</li> <li>• May tire or disengage</li> <li>• May need redirection or encouragement</li> </ul>	<ul style="list-style-type: none"> <li>• Focuses attention on teacher and/or materials</li> <li>• Displays pleasure and/or interest in the activity</li> <li>• Questions or comments</li> <li>• Completes the activity</li> <li>• Repeats or continues to work with activity after teacher demonstration</li> </ul>

## APPENDIX F: INSTRUCTIONAL BELIEF SCALE

Rate the following statements about teaching three- and four-year-olds.		Strongly Disagree	Disagree	Neutral/ Not sure	Agree	Strongly Agree
1)	Preschoolers are interested in recognizing print around them in the world.	1	2	3	4	5
2)	Preschoolers can use print or writing attempts to communicate with other children.	1	2	3	4	5
3)	It is important for preschoolers to count 1-10 by rote.	1	2	3	4	5
4)	Preschool teachers do not need to be concerned about a four-year-old's reading and writing development.	1	2	3	4	5
5)	It is important to adjust an activity to each child's level.	1	2	3	4	5
6)	Preschoolers explore and enjoy reading and writing before they know how to recognize all letters or spell correctly.	1	2	3	4	5
7)	Rhyming is too hard for most preschoolers.	1	2	3	4	5
8)	Understanding the concepts of area and volume is too hard for most preschoolers.	1	2	3	4	5
9)	Teachers should join with children as they play in the different centers of the classroom.	1	2	3	4	5
10)	Preschool child can understand simple graphs.	1	2	3	4	5
11)	Children should be taught to identify separate sounds in words (e.g., first, middle or last sound).	1	2	3	4	5
12)	Appropriate math content for preschoolers largely focuses on counting and numeral recognition.	1	2	3	4	5
13)	Preschoolers can use invented spelling.	1	2	3	4	5
14)	Preschoolers are able to show understanding of higher level math concepts (e.g., addition, area, volume).	1	2	3	4	5