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Examining Associations between Classroom Environment and Processes and Early Mathematics Performance from Pre-Kindergarten to Kindergarten

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One benefit of the No Child Left Behind legislation (2001) has been the increasing attention on the importance of the skills learned in the pre-kindergarten period for later academic achievement (Denton & West, 2002; National Mathematics Advisory Panel, 2008; Whitehurst, 2001). There is a growing awareness that mathematics skills in kindergarten and beyond are influenced by the formal and informal mathematics skills acquired in the pre-kindergarten classroom. Indeed, policy makers, researchers, and educators are now arguing that pre-kindergarten mathematics instruction must be recognized as a critical factor affecting young children's mathematics learning at school age (Ginsburg, Lee & Boyd, 2008). The National Mathematics Advisory Panel's final report (2008) has recommended using a research-based, streamlined mathematics curriculum in pre-kindergarten to give children a strong start in conceptual understanding of mathematics. In addition, the National Association for the Education of Young Children and National Council of Teachers of Mathematics (2002) issued a joint statement affirming the importance of high quality, challenging, and accessible mathematics instruction in broad areas of number, operations, geometry, measurement, and algebra.

Development of Mathematics Concepts

Research evidence supports the notion that knowledge of foundational mathematical concepts begins during infancy, and important changes in mathematical skills have been documented during the first five years (Geary, 1994; Sarama & Clements, 2009). For example Gelman and Gallistel (1978) noted that young children, two to four years of age, show considerable understanding of the underlying principles of counting. Research studies provide evidence of skills related to other mathematics concepts in the pre-kindergarten years such as, counting, numerical comparison, subitizing small quantities, number transformations, estimation and number patterns (Berch, 2005; Case, 1998; Griffin & Case, 1997; Jordan, Kaplan, Olah, & Locuniak, 2006; Mix, Huttenlocher, & Levine, 2002). In a review of the literature, Fuson (1992) describes how mathematics skills progress through the sixth grade, moving from simple addition and subtraction of sums through 10, counting objects, reading and writing symbols to 20, and solving simple addition and subtraction word problems to multi-digit whole numbers (i.e., the base-ten system of numeration) and multi-digit addition and subtraction. Rittle-Johnson and Siegler (1998) and Rittle-Johnson, Siegler, and Alibali (2001) demonstrated that growth in mathematics problem solving is related, in part, to the strength of the association between conceptual and procedural knowledge--which both develop in an iterative fashion. Thus, there is an evidence-based framework for considering the developmental trajectory of mathematics concepts in young children before they enter formal schooling.

The Role of Classroom Environment

Ginsburg, et al. (2008) recommended an examination of conditions that stimulate children's mathematical performance and suggested the classroom environment may play an important role. In recent years, a body of research has emerged pointing to the contributions to children's learning from pre-kindergarten program quality as indexed by structure and process elements in the classroom (e.g., Pianta & Hamre, 2009). Pianta, Barnett, Burchinal, and Thornburg (2009) describe structural elements in the classroom as "those aspects of the programs that describe the caregiver's background, curriculum, or easily observed or reported characteristics of the classroom or program" (p. 66). Structural elements include physical space, routines, materials, and other non-interactive elements that are often related to licensing regulations or accreditation. In contrast, classroom process elements "refer to children's direct experiences with people and objects in the child care setting, such as the ways teachers implement activities and lessons, the nature and qualities of interactions between adults and children…. and the availability of certain types of activities" (p. 66). Process elements include the possible opportunities for people to interact with children and the context of the classroom environment.

The Early Childhood Environment Rating Scale – Revised (ECERS-R; Harms, Clifford, & Cryer, 2005) is a frequently used measure of classroom environment quality consisting of seven subscales (space and furnishings, personal care routines, language reasoning, activities, interactions, program structure, and parents and staff). While most of the ECERS-R subscales relate primarily to structure elements, two subscales include both structure and process items. The Language-Reasoning subscale includes items that describe how staff members interact with children around materials and activities (e.g., "Some activities used by staff with children to encourage them to communicate", "Children encouraged to talk through or explain their reasoning when solving problems", "Some staff-child conversation"). The Interaction subscale includes items to characterize staff-child interactions around supervision and discipline as well as child-child interactions (e.g., "Some positive staff-child interaction", "Staff give children help and encouragement when needed", "Staff actively involve children in solving their conflicts and problems", "Staff respond sympathetically to help children who are upset", "Staff help children develop appropriate social behavior with peers"). Additional descriptions of these subscales are in Table 1.

Process elements, such as those measured with the Language-Reasoning and Interations subscales of the ECERS-R, are included in descriptions of classrooms indicative of high environmental quality (Peisner-Feinberg & Burchinal, 1997). The structure/process items of the Language-Reasoning and Interactions subscales offer the opportunity to examine how these elements of the classroom environment may be related to children's growth in mathematics scores. In this study, we used classroom rating from the two subscales (Language-Reasoning and Interactions) of the ECERS-R that include both structure and process items obtained in pre-kindergarten as predictors of growth of children's Test of Early Mathematics Ability-3 (TEMA-3; Ginsburg & Baroody, 2003) performance from three time points - the beginning and the end of pre-kindergarten and mid-year of kindergarten.

It is important to note that the observations used to score the ECERS-R are not specific to individual academic content – such as mathematics or literacy – but are general in nature. Nevertheless, relations between ECERS scores and academic outcomes have been reported. For example, Mashburn (2008) used principal components analysis to derive a preschool process variable reflecting social interaction quality that included ECER-R Interaction scores along with scores on two other observation instruments. High scores on this factor were found to relate to higher academic and language assessments (letter-word knowledge, phonological awareness and mathematics, Woodcock, McGrew, & Mather, 2001; receptive vocabulary, Dunn & Dunn, 1997; and oral language skills, Carrow-Woolfolk, 1995) at the end of preschool. Thus, in the present study we used the ECERS-R to examine our research questions concerning how the subscales scores for Language-Reasoning and for Interactions relate to growth of mathematics skills.

Children with Differing Abilities

The children participating in this study were enrolled in public pre-kindergarten programs, with enrollment based on family income eligibility. It was expected that children entering these pre-kindergarten programs would show wide variability in their mathematics performance based on decades of research documenting the impacts that low income, low parental education, and less stimulating home environments can have on children's cognitive development (see Bradley & Corwyn, 2002, for a review). Bowman, Donovan, and Burns (2001) reported that preschool programs can be particularly important for enhancing school readiness for children from low income and educationally disadvantaged families. Gaining a better understanding of how performance on TEMA-3 assessments is influenced by elements of the classroom environment is important.

We also explored differences in the role of classroom environment on growth of TEMA scores related to initial performance scores in the fall of pre-kindergarten. In this study the mean TEMA-3 score (M = 83.86) of children when they entered their pre-kindergarten programs was more than one standard deviation below the standardization mean (M=100, SD=15). These mean scores are comparable to the mean TEMA-3 score of 82.79 reported by Meisels, Xue, and Shamblott (2008) from a study of children enrolled in comparable pre-kindergarten programs and of comparable ages. However, in our sample there were also children performing at or above the standardization mean. These children performing at a higher level on the TEMA-3 at pre-kindergarten entry would not be described as "gifted" when compared to the general population, but they clearly entered their pre-kindergarten programs with stronger mathematics skills compared to their classmates, some of whom were performing two standard deviations below the standardization mean. Instead of seeking to identify students as "gifted" under traditional definitions, we chose to examine a broader pool of high-potential children compared to their peers. Thus, we used Lohman's (2005) differentiation of "high-accomplishment" and "high-potential" students. Given the children's enrollment in pre-kindergarten programs designed for those at "high educational risk", many children may not have had opportunities to develop the skills assessed on the TEMA-3, thus making comparisons within the sample and considering a broader range of students more critical. Furthermore, children who come from economically disadvantaged homes less frequently score at the highest levels of achievement (Plucker, Burroughs, & Song, 2010) and the achievements of children living in poverty and/or who are racial/ethnic minorities are often overlooked for gifted education (Olszewski-Kubilius & Thomson, 2010). Thus, identifying the classroom needs of "high-potential" children from this population is important.

Within this sample of high educational risk children, we investigated how the growth mathematics skills in children with differing initial levels may be related to elements of their classroom environments. We hypothesized that there would be differential relations between mathematics skills growth and classroom environment for different groups. Finally, we investigated whether differential percentages of high-performing and low-performing children in a classroom would predict growth of TEMA-3 scores.

Methodology

Participants

The children in this study and the data collected were part of a larger longitudinal study exploring the role of mathematics curricula and activities and children's mathematics skills. All participants were recruited from state-funded pre-kindergarten classrooms and Head Start pre-kindergarten classrooms providing comprehensive early education services within two Mid-western states. These pre-kindergarten classrooms serve ethnically diverse children of low-income families. At the start of the study (fall of the school year), there were 371 pre-kindergarten children (176 male; mean age = 53.4 months). In the spring, 333 of the pre-kindergarten children (166 male, mean age = 60.4 months) were tested. In the mid-year of kindergarten (January-March), 289 children (140 male, mean age = 70.1 months) were tested. Missing data from children at one or more points across the study period were due to children not enrolling in kindergarten as a result of not meeting age cut-offs for or not seeking kindergarten enrollment [33%], random exclusion of one twin from a twin pair [<1%], study children moving to non-study pre-kindergarten classrooms [*n* = 22%], or study children moving out of the region (44%). All children with data at one or more time points were included in analyses as hierarchical linear modeling (HLM) allows for time-unstructured data. All children were identified by their pre-kindergarten teachers as typically developing and speaking English as their primary language at school. Information on children's racial/ethnic backgrounds was obtained in pre-kindergarten or kindergarten; the distribution was 6.9% African-American, 65.5% Caucasian, 3.4% Latino/Hispanic, 3.4% other or mixed-race. Race/ethnic information was missing for 20.7% of the sample. The 46 pre-kindergarten classroom teachers (all females) averaged 12.33 years of teaching (SD = 7.03; Range = 0 to 27 years). Seventeen teachers reported that they held Associates' degrees or lower, 14 teachers held Bachelor's degrees, and 15 teachers held Master's degrees. Teaching experience and highest level of education data for two teachers were unavailable.

Classrooms were located in schools distributed across five counties and included half-day programs for four days per week, full-day programs for four days per week, and full-day programs for five days per week. Each classroom had a lead teacher and a teacher assistant. Eligibility for enrollment in the programs was based on the following criteria: at least four years of age and annual family income at or below federal poverty level or suspected developmental delay.

Measures

The measure of children's mathematics performance was the Test of Early Mathematics Ability – 3 (TEMA-3: Ginsburg & Baroody, 2003), a standardized instrument designed to assess conceptual understanding and skills for children aged 3:0 to 8:11 years. The TEMA-3 (Form A) was individually administered to children by trained researchers using the standard picture book and tokens. Each child's responses were scored on a record form and raw scores were transformed to Math Ability scores (Mean = 100, SD = 15). The test consists of 72 items to measure subitizing (i.e., determining the total number of objects without counting), counting (e.g., *"Count out loud for me.*"), number knowledge (e.g., "*What number is this?*), set comparison (e.g., "*Which has more dots?"*), addition (e.g., *"How much are two and one altogether?"*), subtraction (e.g., *"How much is two take away one?"*), multiplication (e.g., *"How much is 5 x 0?"*), and division (e.g., *"If the girls shared the cookies fairly how many would they each get?"*). Items are administered using age to determine item entry level. Basal and ceiling levels are established based on number of consecutive correct or incorrect items. The administration of the TEMA-3 requires approximately 45 minutes. According to the examiner's manual (Ginsburg & Baroody, 2003), the two-week test-retest reliability of the TEMA-3 is .82 and the Cronbach's alpha values for 3- and 4- year-old participants are .92 and .93, respectively. The Cronbach's alpha for the current sample was .80 in Fall 2007 and .85 in Spring 2008.

Classroom environment was rated using the Early Childhood Environment Rating Scale – Revised (ECERS-R; Harms et al., 2005). ECERS-R observations for each classroom occurred in the fall and were conducted by trained researchers. Administration of the ECERS-R required approximately 2 to 3 hours and all six subscales were scored. Likert scores *(*1 = inadequate, 7 = excellent*)* were determined for each subscale based on the presence or absence of specified indicators within each subscale. Although all subscales were scored, only scores for two of the six subscales (Language-Reasoning and Interaction) were used in the analyses reported in this manuscript. Harms et al. (2005) reported a mean weighted Cohan's Kappa of .55 for the child-related items to provide evidence of individual item reliability and a Chronbach's alpha of .93 as an indicator of internal consistency of the subscales. Perlman, Zellman, and Le (2004) reported an internal consistency estimate of the ECERS-R of .95.

Procedure

The University's Institutional Review Board approved this study. In the fall (September to October) and spring (March to April) of the pre-kindergarten year and at mid-year (January-March) of the kindergarten year, trained researchers and graduate research assistants assessed children's mathematics skills using the TEMA-3. Children participated in one or two assessment sessions at each time point depending on how quickly they completed assessments and the amount of time available for the child to be out of the classroom. Each child was tested in a quiet area of the school and received stickers and an age-appropriate toy or game upon completion. The ECERS-R observations took place in the fall of the pre-kindergarten year. All observations occurred so that the common elements in the classroom daily routine (e.g., arrival, circle time, center time, outside play) could be observed across classrooms. The pre-kindergarten teachers received a gift certificate upon completion of the teacher background questionnaires.

Results

First, the data for all children were analyzed. The descriptive statistics (means, standard deviations) were used to characterize the participants (shown in Table 2). A three-level hierarchical linear model (HLM; Raudenbush & Bryk, 2002) using HLM 6.08 (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2004) was used to examine the contribution of classroom quality, as measured by ECERS-R scores for Language-Reasoning and Interactions, to children's growth in TEMA-3 scores. The models used time-points nested within children nested within pre-kindergarten classes, thus accounting for the non-independence of units.

Shown in Table 3 are the percentages of children in the sample whose mathematics abilities were measured in each of three waves: at the beginning of pre-kindergarten (Wave 1: August to October, with most occurring in September), the end of pre-kindergarten (Wave 2: March to May, with most occurring in April), and the middle of kindergarten (Wave 3: January to April, with most occurring in February). Because the TEMA-3 was administered in different months, time was measured by month of administration, beginning with August; thus, the growth slope can be interpreted as growth per month.

The analyses examined whether Language-Reasoning and Interactions characteristics of the classroom were differentially related to growth of TEMA-3 scores based on initial performance levels at pre-kindergarten entry. The TEMA mean of the full sample was low, as had been anticipated in this sample of preschool children. On average, children started preschool with a TEMA-3 score of 83.43, just over 1 standard deviation below the mean for the TEMA standardization sample. A dummy code was created using a mean split indicating that a child's baseline TEMA-3 score was above or below the average score for the sample at baseline measurement. With the mean split, 47% of the sample (174 children) was high-performing and 53% (197 children) was low-performing. About half the sample was female. For the full sample, there was an average of about 8 children per class. Of the 48 classes, 26 had more low-performing than high-performing children, and 22 had more high-performing than low-performing children. For the model examining differences by initial performance, we entered the mean-split dummy code variable as a child-level predictor of the intercept (TEMA-3 scores at the beginning of pre-kindergarten) and growth slope.

The ECERS-R Language-Reasoning and Interactions subscale scores were used as predictors of the growth slope for all children, and then used in separate analyses as predictors of the growth slope for low-performing children and the differential in the growth slope for high-performing children. The classroom Language-Reasoning average scores ranged from 1.75 to 7.00, and the classroom Interaction average scores ranged from 1.80 to 7.00. These variables were entered into the analyses grand-mean centered so that the intercept for the growth slope was for a child in a classroom with an average level of Language-Reasoning (5.07) and an average level of Interactions (5.82). These results, examining baseline TEMA-3 scores and the growth slope for all children, are in Table 4. The average TEMA-3 scores at pre-kindergarten entry of 83.43 (γ_{000}) were found to increase by 0.69 points each month (γ_{100}). Neither the ECERS-R Language-Reasoning (γ_{101}) nor the Interactions scores (γ_{102}) had a statistically significant relationship to children's growth over time. However, there was statistically significant variability in the growth slope ($\square_{11}$ = 0.14, $p < .001$) suggesting that further examination of the model was warranted.

Next, we added whether students were classified as high-performing relative to their peers, as a predictor of both their initial TEMA-3 score and their growth in TEMA-3 scores. As would be expected, whether students were high-performing explained a substantial amount of between-student variability in the intercept (85%) and also between-class variability in the intercept (72%). Additionally, children's initial status as high-performing explained 18% of the variability between classes in TEMA-3 growth slopes.

To explore the growth of initially low-performing children and the differential from that for initially high-performing children, we added the ECERS-R predictors of those two slopes. Calculated from Table 5 and illustrated in Figure 1 are the model-predicted TEMA-3 scores for children who entered pre-kindergarten with low compared to high mathematics scores. For the low-performing group, the model predicted mean was 74.32 (γ_{000}) in August of their pre-kindergarten year, whereas children in the high-performing group had a model-predicted TEMA-3 score of 93.77 ($\gamma_{000} + \gamma_{101}$). Although the scores of children in the low-performing group who were in classrooms of average Language-Reasoning and Interactions scores grew at a rate of

0.78 points per month (γ_{100}), children in the high-performing group in similar classrooms grew at a rate of about 0.54 points per month (0.78 – 0.24; $\gamma_{100} + \gamma_{110}$). For the children in the low-performing group, the Language-Reasoning in the classroom did not have a statistically significant association with their growth (γ_{101}). In contrast, for each unit above the average the classroom scored on Interactions, the scores of children in the low-performing group grew at an additional rate of 0.13 points per month (γ_{102}), which just missed statistical significance ($p = .053$). For children in the high-performing group, the classroom's Language-Reasoning score had a statistically significant and positive relation with ($p = .049$) children's scores, increasing their growth rate by 0.16 points per month (γ_{111}). The classroom's Interactions scores had a statistically significant but negative association with ($p = .021$) those children's scores, decreasing their growth rate by 0.20 points per month (γ_{112}). Figure 1 illustrates the differences in baseline TEMA-3 scores, growth in TEMA-3 scores, and the association between classroom Language-Reasoning and Interactions scores and growth of children's scores in the low- and high-performing groups. Adding these predictors of the growth slope explained an additional 17% of variability between classes, suggesting that they do have predictive power but there are other variables not examined in this study that also explain differences in changes in mathematics achievement, as one would expect.

Given that about half of the classes had more low-performing children and about half had more high-performing children, post-hoc analyses were conducted to determine if having a greater proportion of high-performing children in the classroom was related to TEMA scores. Analyses revealed that neither the proportion nor the number of high-performing children in a class was related to the growth trajectory of TEMA-3 scores for either the low-performing or high-performing children ($p > .10$).

Discussion

Results from this study point to three major findings. First, the growth of mathematics skills from pre-kindergarten to kindergarten for the full sample varied between classes but was not significantly associated with the elements of the classroom environment selected for study. Second, classroom elements were differentially related to growth of mathematics scores depending on children's scores at pre-kindergarten entry. Third, overall differences between high- and low-performing children at pre-kindergarten entry are evident in their growth through kindergarten.

The mathematics scores of the children in the present study increased across the three assessment points during the two-year span of the study. These increases are not unexpected given that participation in pre-kindergarten programs are known to influence the growth of children's cognitive skills, nor is it unexpected that pre-kindergarten skills are linked to kindergarten skills. Indeed, parents, educators, administrators, and other stakeholders, such as the funders of pre-kindergarten programs (local, state, and federal agencies as well as faith-based organization), expect that children attending these programs will benefit from their experiences. The steady growth of mathematics skills found in this study shows that there are improvements in mathematics knowledge in young children despite the lament that "the potential to learn mathematics in the early years of school is not currently realized" (page 1, National Research Council, 2009). This growth is especially important since the scores of the full sample of children at the beginning of pre-kindergarten were found to be low – one standard deviation below the standardized mean – but by the end of pre-kindergarten these scores are within one standard deviation of the mean and remain so into the mid-year of kindergarten.

In this study, the role of structure and process elements in the classroom environment, to the extent these are reflected in the Language-Reasoning and Interactions subscales of the ECERS-R, were examined. We anticipated that our findings would support those of the National Center for Early Development and Learning pre-kindergarten study (Bryant, Clifford, Early, & Little, 2005) concerning the importance of focusing on opportunities for teacher-child interactions to raise instructional quality so that pre-kindergarten children are ready for kindergarten. "Effective teaching in early childhood education requires skillful combinations of explicit instruction, sensitive and warm interactions, responsive feedback and verbal engagement or stimulation internationally directed…" (Pianta et al., 2009, p. 71). The two ECERS-R subscales under study here reflect these elements of effective teaching.

We found that elements of effective teaching were differentially associated with growth in children's TEMA-3 scores depending on their scores at entry into pre-kindergarten. Specifically, the growth of children with low scores at pre-kindergarten entry was positively related to Interactions, while that of children with higher scores was negatively related. The fact that this component of classroom quality emerged as a differential contributor to children's mathematics performance can be traced to the indicators of the construct. The ECERS-R Interaction items focus on supervision of and staff interactions with children. Teachers in classrooms with many of these components may be more attentive and sensitive to children's physical, emotional, and cognitive needs. Clements and Sarama (2009) summarized the importance of the teacher's role, "Successful teachers interpret what the child is doing and thinking and attempt to see the situation from the child's point of view. Based on their interpretations, they conjecture what the child might be able to learn or abstract from his or her experiences"

(p. 61). For children with low scores, the structure provided by teachers and staff through close attention to their interactions may be the important ingredient needed by low-performing children to enable the development of their mathematics skills.

In contrast, the growth of mathematics skills in more advanced learners was negatively related to Interaction scores, such that these children had less mathematics skill growth in classrooms where there were high Interaction scores. For these children, rather than needing the structure resulting from close teacher-student interactions, growth of mathematics skills seemed to benefit from encouragement of reasoning and other verbal skills that are components of the Language-Reasoning ECERS-R subscale. High classroom scores on the Language-Reasoning scale reflect the extent to which pre-kindergarten teachers stimulate conversations with children that include reasoning skills, both formally and informally, during children's activities. For example, classroom observers note whether teachers encourage children to talk through or explain their reasoning when solving a problem or puzzle. Such interactions encourage a deeper understanding of the concepts. For the children with higher scores, opportunities to engage in communications around these activities appear to support their mathematics skills.

The third major finding relates to the growth of mathematical skills that continue to show a relationship to the quality elements present in the pre-kindergarten classrooms even in kindergarten. That strong mathematics and other academically-related skills, such as literacy, at kindergarten entry are important for the development of proficient skills at the end of kindergarten and into first grade has been well demonstrated by Denton and colleagues (Denton & West, 2002; West, Denton, & Germino Hausken, 2000). However, in our study, we were able to show that the strengthening of mathematics skills reflected in TEMA-3 scores measured at the entry until the end of pre-kindergarten were maintained at the mid-point of kindergarten.

These findings are important because of the different perceptions held by stakeholders about what is optimal for the education of young children (Lee, 2004; Lynch, Anderson, Anderson, & Shapiro, 2006). For example, professional organizations, parent groups, and teachers have expressed concerns about the diminished role of play in the curriculum, the addition of more academically-oriented content (e.g., numeracy), and the use of frequent assessments and monitoring to gauge children's progress in learning (Almon, 2004). It is noteworthy that expressions of these concerns and a growing reliance on research findings are used in different ways to argue for and against educational practices and decision-making about early childhood education programs. However, evidence from literacy studies show that teacher-child interactions have important and long-lasting effects on the language and literacy development of young children as do the experiences children have at home (Dickinson & Tabors, 2001). Teacher-child and parent-child interactions also are important for the development of mathematics skills. Klibanoff, Levine, Huttenlocher, Vasilyeva, and Hedges (2006) found a significant relationship between mathematics input in teacher speech to the growth in mathematical skills with 4 and 5 year old children. Levine, Suriyakham, Rowe, Huttenlocher, and Gunderson (2010) report that "number talk" between parents and their children during the toddler period predicted children's knowledge of cardinality in the preschool period. More work is needed so that the mathematics knowledge and instructional styles of teachers in early childhood education setting and the activities and engagement of parents with their young children around mathematics are similar to the levels seen around literacy. For "every child (to) start school ready to learn" (National Education Goals, 1998) at kindergarten entry, mathematics skills must be strongly and consistently emphasized as important curriculum elements in pre-kindergarten classrooms, and there must be increased attention to how different instructional styles can be used to benefit young children with different initial abilities.

Finally, it is important to comment on the mathematics performance of children in the sample at beginning of pre-kindergarten. Nearly 50% of the sample was performing well on the TEMA-3 at pre-kindergarten entry. Although most of these high-performing children would not be described as traditionally "gifted" based on their TEMA-3 test scores compared to the national sample, they do show great promise, particularly in comparison with their peers. Children who are economically disadvantaged are not only at high education risk, they are also at risk of not being identified as gifted when traditional indicators of giftedness are used (e.g., IQ, achievement and cognitive skills assessments). It is important that children with promise be identified early – ideally in preschool – and provided with supportive education environments that can enable them to thrive. Olszewski-Kubilus and Thomas (2010) recommend as avenues needed to address economic and racial/ethnic achievement gaps in the US the development of supportive plans for individual children that consider their talents and the strengths and weaknesses of their environments (school, family, and community), and engagement of children in enrichment programs that function as preparatory programs to develop their talents. This approach is similar to the recommendation of Borland and Wright (1994) to develop programs to recognize "undeveloped potential". Applied in early education, these approaches may yield big outcome for little children, particularly if these high potential students are provided supportive classroom environments. This study sheds light onto the differential effects of classroom environment on young children with high potential compared to their peers, even when the definition of "high potential" is applied broadly.

Limitations

Although findings reported here support the hypothesis that elements of the classroom environment relate to children's mathematics learning in pre-kindergarten and kindergarten, several limitations to this study should be mentioned. First, we did not obtain in-depth measures of the classroom processes involved in the interactions between teachers and children or measures of classroom processes specifically related to mathematics activities in the classroom. While the ECERS-R is a frequently used measure of classroom environment and a widely used tool for early childhood practitioners, it is not designed to be a process measure of the classroom environment even though some subscales contain process components. The addition of a measure such as the Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2007) would provide greater focus on the processes used by teachers in their classrooms.

Second, the participants in this study were enrolled in Head Start and public pre-kindergarten programs and may not represent the array of classroom environments, teacher instructional practices, and children's performance that might come from classrooms representative of broader early childhood education settings. Such broader sampling of classrooms is characteristic of studies examining the large data sets generated from the National Center for Early Development and Learning Multi-State Study of Pre-Kindergarten and the NCEDL-NIEER State-Wide Early Education Programs Study, (e.g., Howes, 2008; Mashburn et al. 2008). While these studies did not examine the influence of classroom environment on the performance of children with different initial performance levels, such an examination is needed.

Implications

This study has implications for pre-kindergarten teacher credentialing, school psychologists, and using the classroom environment to target emergent mathematics as important content knowledge in pre-kindergarten. The National Mathematics Advisory Panel (2008) recommends that teachers in Head Start and other programs serving pre-kindergartens be more aware of the importance of early mathematical knowledge. Researchers in mathematics education want to know more about children's learning trajectory and what factors in the learning environment or the child's background affect this learning (Sarama & Clements, 2009). The National Research Council (Bowman et al., 2001) recommended the critical need for well-prepared pre-kindergarten teachers who know the big ideas in academic domains, including mathematics. A more recent National Research Council (2009) conclusion called for adults who can *instruct* and *support* in order for pre-kindergarten children to build and expand their ability to mathematize. A better understanding of the relationships between teacher mathematical instructional practices and classroom environment for children of differing initial performance levels will broaden the knowledge of how these factors can improve the teaching of mathematics and affect future children's learning and achievement. Finally, it is critical that children with high potential be identified early and provided with the supports in early childhood classrooms that will enable them to learn and achieve at high levels. The use of multiple indicators of "high potential" in children at high education risk will aid in this effort.

Table 1
Selected ECERS-R Subscales and Items

Subscale	Focus	Examples
Language-Reasoning	- Books and pictures - Encouraging children to communicate - Using language to develop reasoning skills - Informal use of language	- Books relate to current activities or themes - Staff link children's spoken communication with written language - Staff encourage children to reason throughout the day, using actual events and experiences - Children are asked questions to encourage them to give longer and more complex answers.
Interaction	- Supervision of gross motor activities - General supervision of children - Discipline - Staff-child interactions - Interactions among children	- Staff talk with children about ideas related to play - Balance between child's need to explore independently and staff input into learning - Staff use activities to help children understand social skills. - Staff seem to enjoy being with children

Table 2

Descriptive Statistics Describing Full Sample, Low and High Mathematics Ability Children, and Classrooms

	Full sample	Low[1] Children	High[1] Children
Fall pre-kindergarten TEMA-3 scores	83.43 (11.91)	74.32 (4.75)	93.77 (7.93)
Spring TEMA-3 scores	89.65 (13.98)	81.80 (11.29)	98.29 (11.32)
Midyear kindergarten TEMA-3 score	95.61 (14.06)	88.15 (13.16)	103.85 (9.78)
Target children per classroom	8.23 (1.96)	4.38 (1.93)	3.85 (1.91)
Classroom ECERS-R Language-Reasoning Sores	5.07 (1.22)	--	--
Classroom ECERS-R Interaction scores	5.82 (1.21)	--	--

[1] Children were classified as "low" or "high" performing based on whether they fell below or above the mean TEMA-3 score for the sample at baseline (beginning or pre-kindergarten) measurement.

Table 3

Month of TEMA Administration

Month	*n*	%
Wave 1 (beginning of pre-kindergarten)		
August	82	21
September	173	44
October	140	35
Wave 2 (end of pre-kindergarten)		
March	81	23
April	174	49
May	28	28
Wave 3 (middle of kindergarten)		
January	110	36
February	169	55
March	26	9
April	1	0.3

Table 4

Summary of FIML Parameter Estimates for Three-Level Growth Model of Average TEMA Scores for All Children

Parameter	Full model	
	Parameter estimate (SE)	*p*
Intercept		
Baseline TEMA-3 average for all children (γ_{000})	83.43 (0.83)	< .001
Growth slope (averaged for all children)		
Intercept (γ_{100})	0.69 (0.04)	< .001
ECRS-R Language-Reasoning (γ_{101})	0.01 (0.05)	.892
ECRS-R Interactions (γ_{102})	0.01 (0.05)	.780

Note. FIML = full maximum likelihood estimation. Time was measured in months, beginning with August. ECRS-R scales scores were grand-mean centered.

Table 5

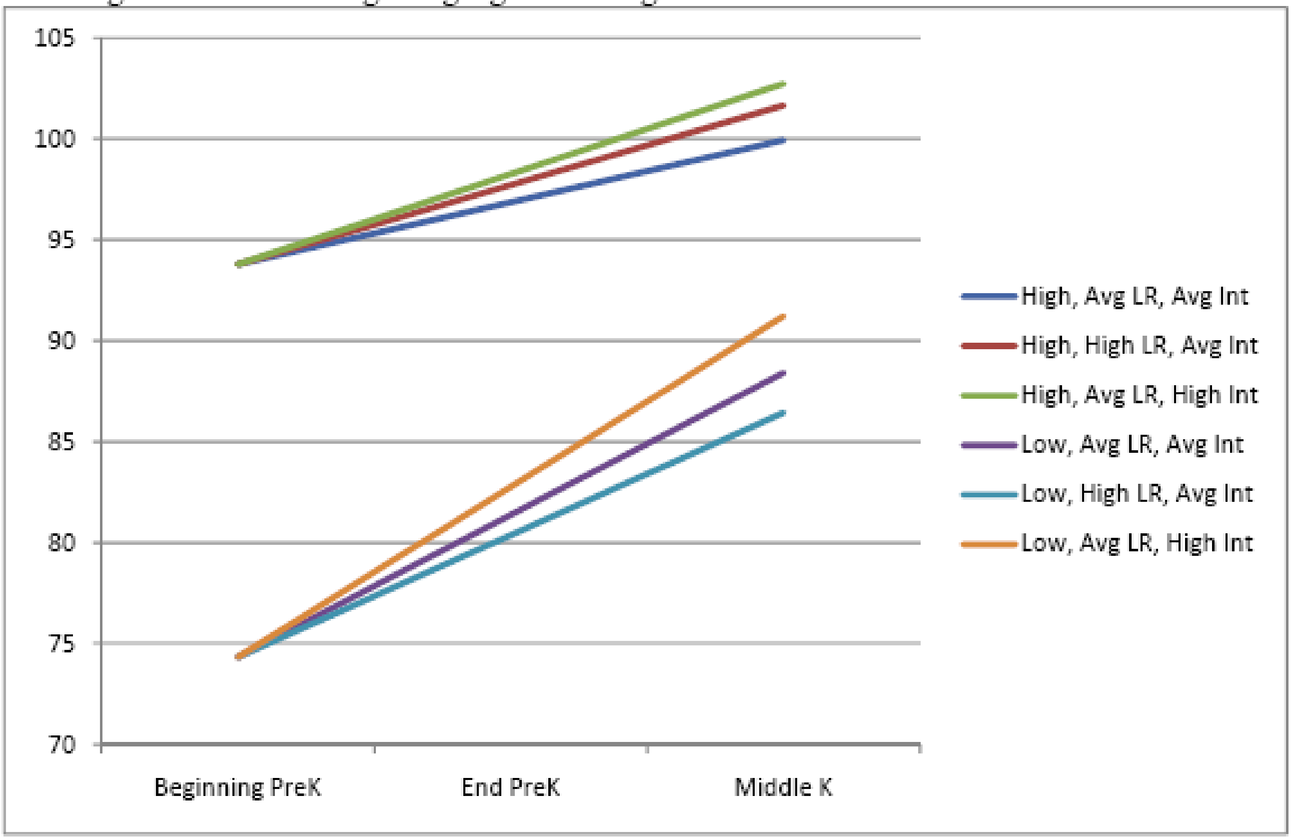
Summary of FIML Parameter Estimates for Three-Level Growth Model of TEMA Scores for Children Beginning Pre-kindergarten with Low and High Mathematics Ability

Parameter	Full model	
	Parameter estimate (SE)	*p*
Intercept		
Baseline TEMA-3 for low children (γ_{000})	74.32 (0.59)	< .001
Differential in baseline TEMA-3 for high children (γ_{101})	19.45 (0.76)	< .001
Growth slope (for low children)		
Intercept (γ_{100})	0.78 (0.06)	< .001
ECRS-R Language-Reasoning (γ_{101})	-0.09 (0.06)	.151
ECRS-R Interactions (γ_{102})	0.13 (0.06)	.053
Differential in growth slope (for high children)		
Intercept (γ_{110})	-0.24 (0.08)	.002
ECRS-R Language-Reasoning (γ_{111})	0.16 (0.08)	.049
ECRS-R Interactions (γ_{112})	-0.20 (0.09)	.021

Note. FIML = full maximum likelihood estimation. Time was measured in months, beginning with August. ECRS scales were grand-mean centered.

Figure 1

Model-predicted growth trajectories for low and high mathematics ability students in classrooms of average and above-average language reasoning and interactions.



Note. High/Low refers to baseline mathematics ability being above or below the baseline TEAM mean. Avg/High LR refers to the classroom having average or high (1 standard deviation above the mean) language reasoning. Avg/High Int refers to the classroom having average or high (1 standard deviation above the mean) interactions.

Reference

Almon, J. (2004). The vital role of play in early childhood education. Retrieved from http://www.iaswece.org/waldorf_education/articles/education_toward_freedom.aspx

Berch, D.B. (2005). Making sense of number sense: Implications for children with mathematical disabilities. *Journal of Leaning Disabilities, 38,* 333-339.

Borland, J. & Wright, L. (1994) Identifying young, potentially gifted, economically disadvantaged students. *Gifted Child Quarterly, 38*, 164-171.

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

Bradley R., & Corwyn, R. (2002). Socioeconomic Status and Child Development. *Annual Review of Psychology, 53,* 371-399.

Bryant, D., Clifford, D., Early, D., & Little, L. (2005). NCDEL Pre-kindergarten Study. *Early Developments*, *9* (1). Chapel-Hill: NC: FPG Child Development Institute. Retrieved from http://www.fpg.unc.edu/~assets/pdfs/eds/ED9_1.pdf

Carrow-Woolfolk, E. (1995). *Oral and Written Language Scales*. Circle Pines, MN: American Guidance Services.

Case, R. (1998). *A psychological model of number sense*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Clements, D., & Sarama, J. (2009). *Engaging young children in mathematics: standards for early childhood mathematics education.* Mahwah, N.Y.: Lawrence Erlbaum Associates.

Denton, K., & West, J. (2002). *Children's reading and mathematics achievement in kindergarten and first grade*. Washington, D.C.: U.S Department of Education, National Center for Education Statistics.

Dickinson, O.K., & P.O. Tabors, eds. 2001. *Beginning literacy with language: Young children learning at home and school.* Baltimore: Paul H. Brookes.

Dunn, L.M., & Dunn, L.M (1997). *Peabody Picture Vocabulary Test – Revised (*3rd ed.). Circle Pines, M: American Guidance Services.

Fuson, K. C. (1992). Research on learning and teaching addition and subtraction of whole numbers. In G. Leinhardt, R. T. Putnam, & R. A. Hattrup (Eds.), *The analysis of arithmetic for mathematics teaching* (pp. 53-187). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Geary, D.C. (1994). *Children's mathematical development: Research and practical applications,* Washington, D.C.: American Psychological Association.

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

Ginsburg, H.P., Lee, J.S., & Boyd, J.S. (2008). Mathematics education for young children: What it is and how to promote it. *Social Policy Report, 22,* 3-22.

Ginsburg, H. P., & Baroody, A. J. (2003). *Test of early mathematics ability – Third edition.* Austin TX: Pro-Ed.

Griffin, S., & Case, R. (1997). Re-thinking the primary school math curriculum: An approach based on cognitive science. *Issues in Education, 3,*1-49.

Harms, T., Clifford, R. M., & Cryer, D. (2005). *Early childhood environment rating scale – Revised*. NY: Teachers College Press.

Howes, C., Burchinal, M., Pianta, R., Bryant, D., Early, D., Clifford, R., & Barbarin, O. (2008). Ready to learn? Children's pre-academic achievement in pre-Kindergarten programs. *Early Childhood Research Quarterly, 23*, 27-50.

Jordan, N. C., Kaplan, D., Nabors Olah, L., & Locuniak M.N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 72,* 153-175.

Klibanoff, S., Levine, S.C., locher, J., Vasilyeva, M., & Hedges, L. (2006). Preschool children's mathematical knowledge: The effect of teacher "math talk". *Developmental Psychology, 42*, 59-69.

Lee, J. (2004). Preschool teachers' beliefs abut appropriate early literacy and mathematics education. Doctoral dissertation, Columbia University.

Levine, S. C., Suriyakham, L.W., Rowe, M.L., Huttenlocher, J., Gunderson, E.A. (2010). What counts in the development of young children's number knowledge? *Developmental Psychology, 46,* 1309-1319.

Lohman, D. F. (2005). An aptitude perspective on talent: Implications for identification of academically gifted minority students. *Journal for the Education of the Gifted, 28,* 333-360.

Lynch, J., Anderson, J., Anderson, A., & Shapiro, J. (2006). Parents' beliefs about young children's literacy development and parents' literacy behaviors. *Reading Psychology, 27,* 1–20.

Mashburn, A.J. (2008). Quality of social and physical environments in preschools and children's development of academic, language, and literacy skills. *Applied Developmental Science, 12,* 113–127.

Mashburn, A. J., Pianta, R. C., Hamre, B. K., Downer, J. T., Barbarin, O. A., Bryant, D., et al. (2008). Measures of classroom quality in prekindergarten and children's development of academic, language, and social skills. *Child Development, 79,* 732-749.

Meisels, S.J., Xue, Y., & Shamblott, M. (2008). Assessing language, literacy and mathematics skills with *Work Sampling for Head Start*. *Early Education and Development, 19*, 963-981.

Mix, K., Huttenlocher, J., & Levine, S. (2002). *Quantitative development in infancy and early childhood.* New York: Oxford University Press.

National Association for the Education of Young Children & National Council of Teachers of Mathematics. (2002). *Early childhood mathematics: Promoting good beginnings.* Retrieved from http://www.naeyc.org/positionstatements/mathematics

National Education Goals Panel. (1998). The National Education Goals report: Building a nation of learners, 1998. Washington, DC: U.S. Government Printing Office.

National Mathematics Advisory Panel (2008). *Foundations for Success: The Final Report of the National Mathematics Advisory Panel,* Washington, DC: U.S. Department of Education.

National Research Council. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity.* Committee on Early Childhood Mathematics, C. T. Cross, T. A. Woods & H. Schweingruber, Editors. Center for Education, Division of Behavioral and Social Sciences and Education, Washington, DE: The National Academies Press.

No Child Left Behind. (2001). Retrieved from http://www.ed.gov/legislation/ESEA02/

Olszewski-Kubilius, P & Thomson, D. (2010). Gifted programming for poor and minority urban students: Issues and lessons learned. *Gifted Child Today*, 33, 58-64.

Peisner-Feinberg, E. S., & Burchinal, M. R. (1997). Relations between preschool children's experiences and concurrent development: The cost, quality, and outcome Study. *Merrill Palmer Quarterly, 43*(3), 451-477.

Perlman, M., Zellman, G.L., & Le, V-N (2004). Examining the psychometric properties of the Early Childhood Environment Rating Scale-Revised (ECERS-R). *Early Childhood Research Quarterly, 19*, 398-412.

Pianta, R. C., Barnett, W. S., Burchinal, M., & Thornburg, K. R. (2009). The effects of pre-kindergarten education: What we know, how public policy is or is not aligned with the evidence base, and what we need to know. *Psychological Science in the Public Interest*, *10*(2), 49–88.

Pianta, R. C., & Hamre, B. K. (2009). Conceptualization, measurement, and improvement of classroom processes: Standardized observation can leverage capacity. *Educational Researcher*, 38, 109-119.

Pianta, R. C., La Paro, K. M., & Hamre, B. K. (2007). *Classroom Assessment Scoring System (CLASS)*—Pre-k [CLASS]. Baltimore: Brookes Publishing.

Plucker, J. A., Burroughs, N., & Song, R. (2010). *Mind the (other) gap! The growing excellence gap in K-12 education.* Retrieved from http://www.nagc.org/uploadedFiles/Advocacy/ExcellenceGapBrief%20(2010%20IU).pdf

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models: applications and data analysis methods.* Thousand Oaks, CA: Sage Press.

Raudenbush, S., Bryk, A., Cheong, Y. F., Congdon, R., Du Toit, M. (2004). *HLM 6,* Chicago: Scientific Software International.

Rittle-Johnson, B., & Siegler, R. S. (1998). The relation between conceptual and procedural knowledge in learning mathematics: A review. In C. Donlan (Ed.), *The development of mathematical skills* (pp. 75-110). East Sussex, UK: Psychology Press.

Rittle-Johnson, B., Siegler, R.S., Alibali, M.W. (2001) Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology, 93*, 346-362.

Sarama, J., & Clements, D. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. New York, NY: Routledge.

West, J., Denton, K., and Germino Hausken, E. (2000). *America's kindergartners*. NCES 2000-070. Washington, DC: National Center for Education Statistics.

Whitehurst, G. (2001). *Do pre-kindergarteners need academic content?* Retrieved from http://www.readingrockets.org/article/410

Woodcock, R., McGrew, K., & Mather, N. (2001). *Woodcock-Johnson III.* Itasca, IL: Riverside.