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Effect of Early Childhood Language Development on First Grade Mathematics Achievement

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Abstract

This article examines the correlation between language, as a sociocultural method through which teaching and learning occur, and children's achievement in mathematics. Data for white and black children (N=1273) from the Study of Early Child Care and Youth Development is used to examine the effect of children's early language development, as measured by the Preschool Language Scale (PLS-3) scores at 54 months of age, on mathematics achievement. Using cross sectional and longitudinal regression models, this research examines mathematics achievement for children at 54 months and at first grade. Findings indicate that high PLS-3 scores at 54 months of age are associated with positive mathematics achievement at 54 months. This correlation persists through first grade, where race is no longer predictive of mathematics achievement.

Move2
step1

step2

step3

Effect of Early Childhood Language Development on First Grade Mathematics Achievement

Researchers have sufficiently documented the disparity between the mathematics achievements of black and white children (Lubienski, 2002; Jencks & Philips, 1998; Entwisle & Alexander, 1990; Stiff & Harvey, 1988). National Assessment of Educational Progress (NAEP) data for 2007 indicated that the gap in mathematics achievement between Black and White

children was 26 points at grade 4 and 31 points at grade 8 (Planty, et al., 2008; Lee, Grigg, & Dion, 2007). Although the gap in mathematics achievement fluctuates in magnitude between various time points, it remains a prominent issue because black children, on average, consistently appear to lag behind white children in measures of academic achievement. Increasingly, researchers have focused on unpacking cultural and social context as a means of understanding some of the variance observed in the mathematics achievement gap among children of different racial and ethnic backgrounds (Moses-Snipes, 2005; Ladson-Billings, 1997, 1995; Tate, 1995; King, 1991).

Achievement in mathematics is often described as the key gatekeeper in U.S. society (Lubienski, 2002); therefore, identification of variance in cultural and social contexts that might assist in narrowing the achievement gap in mathematics is of critical importance. This study explores the association between one type of cultural and social context--language development--and mathematics achievement by examining the relationship between children's language ability and mathematics achievement at 54 months of age. A longitudinal regression model is used to examine changes in children's mathematics achievement between 54 months of age and first grade.

Review of Literature

Studies examining the relationship between language development and mathematics achievement from the perspective of culture suggest that, as children bring their cultural contexts to the classroom, there must be attention to the relationship between cultural context and academic achievement (Lerman, 2001; Stiff & Harvey, 1988; Mehan, 1984). Bronfenbrenner's (1979) ecological paradigm suggested that children's environmental context influenced their experiences, including those related to academic achievement. Some previous studies in this area explicitly examine the correlation between language factors and learning mathematics (Ginsberg, Lee, & Boyd, 2008; Aikens, 1972); others discuss language in the context of mathematics (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Adams, 2003). This study explores the correlation between the development of language ability, which is an expression of cultural or environmental context, and mathematics achievement. That is, the focal point of this study is the correlation between how children who are native-speakers of English develop expressive communication skills and their achievement in mathematics.

Language in its spoken and written context is, according to Adams (2003), a conduit for the language of mathematics, and related to children's metalinguistic awareness. Words, as elements of language, have multiple meanings, which can be confusing to children. Adams finds that it is helpful for students to connect their prior understanding of words to the definitions they find in mathematics. Such connection, which conceptually engages social and cultural contexts, can help facilitate children's understanding of mathematics. Citing Garbe (1985), Adams asserts that grasp of mathematical concepts depends on integration of linguistic, cognitive, and metacognitive skills to comprehend text. This is especially evident as children grapple with word problems, which require a decoding of the text prior to addressing the mathematical questions.

Although the primary focus of this study is the correlation between language development and mathematics achievement, the second focus is the differences between black and white children in these constructs. This focus stems from the emphasis in American society on the racial differences in educational attainment, especially between the aforementioned groups. While some scholars have argued that race is of declining significance (D'Souza, 1995; Wilson, 1978), others have maintained that race does indeed matter, and is evident even in those contexts where mathematics learning and mathematics literacy are important (Martin, 2006). Culture, scholars argue, cannot be ignored in discussions of mathematics pedagogy and literacy (Martin, 2006; Moses-Snipes, 2005; Gutiérrez, 2000; Ladson-Billings, 1995; Tate, 1995).

Method

Participants

The Study of Early Child Care and Youth Development (SECCYD) is a comprehensive longitudinal study initiated by The National Institute of Child Health and Human Development (NICHD) in 1989 to examine questions about the relationship among childcare experiences, childcare characteristics, and children's developmental outcomes. In 1991, a diverse sample of children and their families at 10 locations across the United States agreed to participate in the SECCYD. Locations included Little Rock, AR; Irvine, CA; Lawrence, KS; Boston, MA; Philadelphia, PA; Pittsburgh, PA; Charlottesville, VA; Morganton, NC; Seattle, WA; and, Madison, WI. Recruitment and selection of participants in the SECCYD are described in several documents that are publicly available (see http://secc.rti.org).

The SECCYD sample is comprised of Whites (76.4 %), Blacks (12.9%), Hispanic-Americans (6.1%), Asian-Americans (1.4%), and Native-Americans (.1%). The current study includes 1273 black and white children, which represents 93% of the original sample. The valid *N* for measures varies between 54 months and first grade because some student and their families dropped out of the study.

Measures

Demographic Variables

Age and Grade level data are for children at 54 months and at first grade. The specific time points used in the current research represent the administration periods of achievement tests in the SECCYD study. Administration of standardized cognitive ability testing related to language and mathematics achievement occurs when children are 54 months of age. The second administration of standardized testing of mathematical ability occurs during first grade, which is included in the analysis to ascertain students' mathematics achievement change over time. Race is coded as a dummy variable; thus, results indicate the effects for Black students. Eighty-six percent of the sample is white, and 14% is black. Fifty-two percent of the sample is male, and 48% is female. Household Type defines the relationship to the study child and mother for full-time adult members of the household. When children are at 54 months of age, 83% of the sample is two-parent families, and 17% is single-parent families. Household Type remains stable within first grade data. The Income-to-Needs Ratio is based on annual pre-tax income divided by the poverty threshold for a given household. Values for this variable range from a ratio of .07

to 28.67, and 87% percent of the sample has an income-to-needs ratio greater than 3.0 (an income-to-needs ratio of 1 would indicate that a household's income is equal to the poverty threshold). Mother's Educational Attainment is from a home interview conducted when the study child was at one month of age, and 70% of the sample report education beyond high school. Mother's Age at Child's Birth is from a home interview conducted when the study child was one month of age. The range for this variable is 18 – 46 years, and the average age is 28.

Academic Outcomes

Defined as children's scores on standardized testing, these constructs are operationalized by the Preschool Language Scale-3 (PLS-3) test administered at 54 months, and by the Woodcock-Johnson Psycho-Educational Battery Revised Applied Problems Achievement Test subscale ($\alpha = .82$) administered at age 54 months and at first grade.

The PLS-3 measures children's language development. Among other things, the PLS-3 assesses vocabulary, grammar, morphology, and language reasoning. A number of studies have shown that children's language comprehension can be very different compared to their language production abilities. Thus, studies of language must separately examine these composite factors of language skill to get some sense of the child's linguistic talent. The PLS-3 is organized into two standardized subscales: Auditory Comprehension (AC) and Expressive Communication (EC). The AC scale measures what children "know" or understand, but may not "say", and the EC scale measures what children actually say or produce. This study uses the EC standard score to measure students' linguistic production at 54 months. The possible range of scores for the

PLS-3 EC scale is from 50 to 128, with higher scores indicating a greater ability to communicate by "saying" what the child understands. Values above 100 indicate the raw score was above the mean score of similar students with whom the instrument was standardized.

The Woodcock-Johnson Applied Problems subtest measures skill in analyzing and solving practical problems in mathematics. Higher values are indicative of better command of the skills measured.

Table 1 indicates descriptive statistics for the sample used in this study at both 54 months and first grade. Table 2 provides correlations between mathematics achievement and the predictor variables.

Results

The correlations table indicates that black children score lower in both PSL-3 outcome and mathematics achievement. The coefficient for race and PLS-3 scores is -.356; for race and mathematics achievement at 54 month, it is -.339. The coefficient for race and mathematics achievement at first grade is -.298. While the size of the coefficients are modest, they are all statistically significant at $p<.001$.

In the cross sectional regression models, Model 1 for children at 54 months indicates that, on average, black children, when compared to white children, score 20 points lower on the WJ-R Applied Math subtest. Race *(beta= -.35, p<.001)* accounts for 12% of the variance observed in mathematics achievement in this model. With the addition of PLS-3 scores *(beta= .66, p<.001)* to the model, the difference in mathematics achievement scores between black and white children reduces to six points; however, this model explains 50% of the observed variance. PLS-3 scores are positively associated with achievement in mathematics achievement; however, the lower PLS-3 scores found among black children correlates with lower mathematics achievement. With the addition of demographic variables in the full model for children at 54 months, race *(beta= -.10, p<.001)* and PLS-3 scores *(beta= .62, p<.001)* remain significant predictors of mathematics achievement, as is mother's education *(beta= .10, p<.01)*. However, the explanatory power of the full model does not change from that observed in Model 2.

When we examine the longitudinal regression models in table 3, Model 1 shows that, on average, black students score 14 points below white students in mathematics achievement. Thus, by first grade, the gap in achievement between black and white children reduces. Race *(beta= -.28, p<.001)* explains 8% of the variance observed. With the addition of PLS-3 scores *(beta= .51, p<.001)* in model 2, the gap in achievement reduces to less than 5.5 points. The explanatory power of model 2 accounts for 31% of the variance observed. Controlling for children's mathematics achievement at 54 months *(beta= .42, p<.001)* in model 3 accounts for 40% of the variance observed, and reduces the gap to 3.5 points. Race *(beta= -.07, p<.05)* is still a significant, although less robust, predictor of achievement in mathematics, as are PLS-3 scores *(beta= .24, p<.001)*. In the full model, the gap between in mathematics achievement is less than 2 points; however, race is no longer statistically significant. Prior mathematics achievement *(beta= .40, p<.001)* and PLS-3 scores *(beta= .24, p<.001)* predict students' mathematics achievement in first grade, as does gender *(beta= -.18, p<.001)*. The full model accounts for 43% of the variance observed, which about the same as explained by model 3.

Discussion

It is evident from the full cross sectional regression models that, at 54 months of age, race, PLS-3 scores, and mothers' education are significant predictors of achievement in mathematics. The coefficient for race suggests that, on average, black children have lower achievement in mathematics than white children. Not surprisingly, children whose mothers have higher educational attainment have achievement that is more positive. The same is true for children who score higher on PLS-3 tests.

By the time that children are in first grade, the gap in achievement reduces significantly. Recall that, in the full model for children at 54 months of age, black children scored, on average, almost 5.5 points lower than white children in achievement. By first grade, however, there is only a difference of less than two points between children, and race is no longer a significant predictor. Nor is mother's educational attainment a significant predictor. PLS-3 scores and, as expected, prior achievement in math have larger effect sizes, and are significant predictors of children's achievement in mathematics. The data also indicate that girls, on average, have lower scores than boys, a difference that was not statistically significant at 54 months.

Race, a significant predictor or mathematics achievement among children at 54 months of age, has no statistical significance for children in first grade. It appears that the addition of gender in the full model eradicates any effect of race. Thus, it cannot be argued from these data that differences in children's mathematics achievement in first grade are attributable to race. At this stage, it appears that the most significant indicators of children's ability in mathematics as they move into first grade are expressive communication scores, prior achievement, and gender. Although the association among PLS-3 scores, prior achievement, and first grade achievement are positive, the association with gender is negative. This suggests that girls, on average, score lower on the WJ-R Applied Problems subtest as they move from 54 months to first grade.

Conclusion

This research does suggest that there is, indeed, a correlation between language development and mathematics achievement. The effect of race, thought to be a central factor, does not maintain statistical significance in the full model for first grade. This does not imply that the gap in mathematics achievement between children of different races has been closed. Indeed, research cited elsewhere in this study support findings to the contrary. What this study demonstrates, however, is the correlation between language development and mathematics achievement, irrespective of race. Children who perform well on the PLS-3 tests tend to have higher achievement in mathematics. Gender becomes significant in the full model, although the association with mathematics achievement is negative, and appears to erase any race effects.

Development of pedagogy in mathematics, and teacher training, would do well to consider the correlations discussed in this study. Much remains to be learned regarding children's cognitive development, particularly in the context of language and mathematics. We cannot afford to continue to treat the two as distinct silos of instruction. Although race does not predict mathematics achievement in first grade when gender is present in the equation, this study is suggestive enough of the lower achievement by Black students in PLS-3 scores and mathematics to warrant further study. Future research might explore what elements of language development, specifically expressive communication, are correlated with achievement in mathematics. Further, we need to understand how these elements are incorporated in mathematics learning, and if there are ways in which the structure of the teaching of mathematics can be changed and improved to ensure the success of all students. That is, we need to implement culturally responsive pedagogy in mathematics learning and, indeed, in all learning, that takes into account diversity on linguistic contexts. Mathematics learning and literacy is not distinct from language development; in fact, it builds upon the foundation of language. Understanding and incorporating various cultural approaches to language, and not just for those who are English Language Learners, would be of benefit to many students.

Table 1

Means and Standard Deviations

	54 Months (*N*=951)		First Grade (*N*=852)	
Measure	M	SD	M	SD
Demographics				
Income-to-Needs Ratio	3.63	3.20	4.00	3.04
Mother's Age	28.67	5.57	28.91	5.49
Mother's Education (Recoded)	3.23	1.24	3.29	1.23
Outcome Variables				
PLS-3 (EC)	100.24	20.18	101.64	19.50
WJR Applied Problems	425.03	18.85	471.60	15.45

Table 2

Correlations among Predictors and Outcomes

Table 3

Effect of PLS-3 Scores on Mathematics Achievement at 54 Months and First Grade

Predictors	54 Months (N=951) Model 1 B	Model 1 Beta	Model 2 B	Model 2 Beta	Model 3 B	Model 3 Beta	First Grade (N=852) Model 1 B	Model 1 Beta	Model 2 B	Model 2 Beta	Model 3 B	Model 3 Beta	Model 4 B	Model 4 Beta
Race	-20.05 (1.73)	-.35+	-6.20 (1.41)	-.11+	-5.48 (1.51)	-.10+	-13.86 (1.62)	-.28+	-5.40 (1.49)	-.11+	-3.51 (1.40)	-.07*	-1.91 (1.5)	-.04
PLS-3 Score			.61 (.02)	.66+	.58 (.03)	.62+			.40 (.02)	.51+	.19 (.03)	.24+	.19 (.03)	.24+
WJ-Applied Problems, 54 Months											.37 (.03)	.42+	.35 (.03)	.40+
Gender					.43 (.88)	.01							-5.52 (.81)	-.18+
Household Type					-1.84 (1.32)	-.04							-1.01 (1.18)	-.02
Income-to-Needs Ratio					.01 (.16)	.00							.28 (.159)	.06
Mother's Age					.15 (.10)	-.05							.03 (.09)	.01
Mother's Education					1.55 (.46)	.10**							.45 (.43)	.04
Constant	447.59		370.53		373.92		486.99		436.55		300.91		309.30	
Adjusted R^2	.12		.50		.50		.08		.31		.40		.43	

Notes: Constant and adjusted R^2 are for full models. Numbers in parentheses are standard errors.
* p<.05. ** p<.01. + p<.001 (two-tailed tests).

	1	2	3	4	5	6	7	8	9	10
1. Child's Race	--									
2. Child's Gender	.007	--								
3. Household Type 54M (Recoded)	.384**	-.017	--							
4. Household Type Grade1F (Recode)	.341**	.028	.667**	--						
5. Income-to-Needs Ratio 54M	-.246**	.055	-.267**	-.209**	--					
6. Income-to-Needs Ratio Grade 1	-.255**	.026	-.255**	-.264**	.736**	--				
7. Mother's Age	-.266**	.041	.-268**	-.239**	.384**	.384**	--			
8. Mother's Educ. (Recoded)	-.234**	.061*	-.234**	-.240**	.487**	.526**	.552**	--		
9. PLS-3 54 Mos (Expressive Communication)	-.356**	.167**	-.229**	-.187**	.346**	.346**	.360**	.460**	--	
10. WJ-R Applied Problems 54 M	-.339**	.135**	-.231**	-.140**	.275**	.275**	.283**	.381**	.696**	--
11. WJ-R Applied Problems Grade1	-.298**	-.072*	-.167**	-.186**	.267**	.303**	.266**	.345**	.569**	.598**

*p< .05; ** p< .01 (2-tailed tests).

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