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Block Play Performance Among Preschoolers As a Predictor of Later School Achievement in Mathematics

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Abstract. In 1982, an intact group of 37 preschoolers (age 4) attending a play-oriented preschool were tested using the Lunzer Five Point Play Scale (1955) to obtain a block performance measure. To statistically control for social economic status (SES), IQ and gender, the McCarty Scales of Children's Abilities (1972) were given, the gender determined, and an SES score obtained (Hollingshead & Redlick, 1958). In 1998, after these same participants had completed high school, their records were obtained. Outcome measures for the 3rd, 5th, and 7th grades included standardized tests and report card grades in mathematics. High school achievement was determined by using 1) number of courses, 2) number of honors courses, 3) advanced math courses taken, and 4) grades. While controlling for IQ and gender, the block performance measure was correlated and regressed against these outcome variables. No significance was found at the 3rd- and 5th-grade levels by evaluating report card grades and standardized math scores. At 7th-grade, there was a significant correlation between blocks and standardized math scores, but not report card grades. At the high school level, there was a positive correlation with all high school outcome variables. There was no correlation between block performance and standardized math tests or grades at the elementary school levels. However, at the beginning of middle school, 7th grade, and in the high school grades, a positive correlation between preschool block performance and math achievement was demonstrated.

Historically, the education of preschool children, ages 3 to 5, has produced widely varying philosophies on effective and developmentally appropriate curriculum models (Bereiter & Englemann, 1966; Biber, Shapiro, & Weckens, 1971; Montessori, 1912; Weikart, Rogers, Adcock, & McClelland, 1971). Many of the designers of these early childhood educational models were critical of the theoretical, philosophical, and practical applications used by competing early education models (Bereiter, 1972, 1986; Schweinhart, Barnes, & Weikart, 1993; Schweinhart, Weikart, & Larner, 1986). At the same time, there has been limited research on the long-term effects of specific activities involved in these models. The often-cited research that does exist looks primarily at the whole program's effect (Lee, Brooks-Gunn, Schnur, & Liaw, 1990) as it correlates to later longitudinal effect on larger social variables such as arrests (Bereiter, 1986), welfare, graduation from high school, income, and owning a home (Barnett, 1993; Schweinhart et al., 1993; Schweinhart & Weikart, 1997; Sevigny, 1987). There appears to be limited research evidence (Miller & Bizzell, 1983) that looks at the effects of specific learning activities on young children's later school achievement in reading, math, science, and similar content areas.

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The National Association for the Education of Young Children (NAEYC) guidelines for developmentally appropriate practices (DAP) (Bredekamp & Copple, 1997) support an active play curriculum and self-initiating play activities. The DAP document, although widely disseminated, has limited empirical longitudinal research for the positions taken in the support of play learning and curriculum. It now becomes incumbent upon early childhood researchers to test these DAP assumptions and the specific value of play activities, in terms of how they affect preschoolers' development and learning; learning in their later developmental stages; and their effectiveness at the elementary, middle, and secondary school levels.

Playing with blocks is a central activity in play preschools (Biber et al., 1971; Weikart et al., 1971; Wolfgang & Wolfgang, 1999). Thus, this study attempts to establish a correlation between the levels of young children's block play and their performance in mathematics in later school levels. The generally accepted definition of play would include three large categories: 1) sensori-motor play (large and small motor activity); 2) symbolic play, which involves representational abilities and includes the fantasy play of socio-dramatic play; and 3) construction play, which involves symbolic product formation with blocks, Lego, carpentry, and similar materials (Piaget, 1962; Smilansky, 1968; Wolfgang & Wolfgang, 1999). Although there is a host of empirical research on symbolic play (e.g., Cook, 1996; Dodge & Frost, 1986; Fein, 1981; Pellegrini, 1980), the literature regarding construction play, especially longitudinal studies, is limited (Miller & Bizzell, 1983).

Playing with blocks has historically been a central play activity and found is found in play-oriented preschools (Hartley, Frank, & Goldenson, 1957; Hirsch, 1996; Isaacs, 1933; Provenzo, 1983). Playing with blocks, as a form of construction play (Piaget, 1962), requires the young child to build spatially with large numbers of pieces of unit blocks of wood to produce representations of objects, or products. These products, at the higher levels of block building, can be labeled as imaginary structures representing real objects (Hirsch, 1996; Lunzer, 1955; Reifel, 1996b). Construction play with blocks offers the preschool child the opportunity to classify, measure, order, count, use fractions, and become aware of depth, width, length, symmetry, shape, and space (Hirsch, 1996); thus, one can make a direct relationship with the skills acquired in block play as being foundational for the later cognitive structures (Kamii, 1972, 1982; Piaget & Szeminska, 1952) needed for number and math skills and learning (Fennema et al., 1996; Ginsburg, Balfanz, & Greenes, 1999; Ginsburg, Inoue, & Seo, 1999; Liedtke, 1995; Reifel, 1996a; Vondrak, 1996; Zammarelli & Burton, 1977). The question is whether preschool age children who have intensive play experiences in play-based preschools and who can perform at high levels of block building, also show high levels of mathematical achievement later in formal school settings.

Method

This correlational study uses statistical regression to establish a relationship between preschoolers' levels of block play with later school achievement in mathematics at the elementary, middle, and high school levels, while controlling for SES, IQ, and testing for the effects of gender.

Participants

The 37 participants were selected in 1982 as an intact group of preschoolers enrolled in a play-based preschool (later NAEYC-accredited) located in a southeastern U.S. city of about 212,000 people, a substantial portion of whom were employed in government-related fields. In 1998, the school records of these same participants were obtained after they had completed high school, to permit a longitudinal comparison. Table I provides characteristics of participants in 1982 (when their block-building abilities were measured) and in 1998 (when the longitudinal data was captured).

Ten participants (27%) could not be con-

tacted. The racial mix of these potential participants was six Caucasians, two African Americans, and two Asian Americans. Of these, four were males, and six were females.

Instrumentation

Lunzer Five-Point Play Scale. The Lunzer Scale, based on the Piagetian theoretical framework, was used to rate the preschool players "adaptiveness" in the use of the blocks, as well as their "integration," or play complexity, on a five-point scale. One (or the lowest score) would be defined as "the materials [blocks] are used without regard to their physical or representational properties." The highest score of five would define play as using "the materials [blocks] . . . in a highly insightful manner, adapted to a concept that clearly transcends it." Thus, the higher score signified a more development play performance with blocks. The Lunzer (1955) research reports a .91 reliability with similar age participants, while this research produced a 94 percent interjudgmental reliability.

McCarty Scales of Children's Abilities. A general cognitive score, or IQ, was attained from summing the verbal, perceptual performance, and quantitative scores on the McCarty Scales of Children's Abilities (McCarty, 1972). This test was administered to each participant at the preschool center by a professor of early childhood education. The raw subscale scores were used, because the indexed scores were normed by age level and would, therefore, have reduced variance across participants.

The California Achievement Test. The California Achievement Test (CAT) was administered by school officials in the normal routine of standardized testing, beginning in grade 1, and continuing through grade 8. The CAT score was the mathematics computation and mathematical con-

Table 1

A Comparison of Demographics on Participants at Preschool and High School Levels

		Participants as of 1982 (preschool)	Participants as of 1999 (graduating high school)
Number of participants		37	27
	Ages:	3 years, 10 months to 4 years, 11 months	18 years, 10 months to 19 years, 11 months
Racial mix:	Caucasian	74%	85%
	African American	17%	15%
	Asian American	9%	0%
Gender:	Males	51%	52%
	Females	49%	48%
Age at entry:	Before age 1	42%	55%
	Before age 2	34%	20%
	Before age 3	17%	15%
	Before age 4	7%	10%
SES:	Level 1 (lowest)	20%	Not Available
	Level 2	29%	
	Level 3	36%	
	Level 4	11%	
	Level 5 (highest)	3%	
Type of school:	Public school	-	81%
	Private school	-	4%
	University lab school	-	15%
Post- secondary education:	Attending	-	65%
	Not attending	-	17%
	Unknown	-	8%

cepts, using the national percentile score ranging from 1 to 99 points. Scores on tests administered at grades 3, 5, and 7 were used for computational purposes.

Mathematics Grades. Report card letter grades on mathematics, taken from the participants' elementary records (grades 1 through 5), were scaled as 0 (U-unsatisfactory), 1 (N-needs improvement), 1.5(Sminus-satisfactory), 2(S-satisfactory), 2.5 (S plus-satisfactory), and 3 (E-excellent). Middle school (grades 6 through 8) letter grades on mathematics taken from the participants' school records were scaled as 0 (F-failure), 1 (D-below average), 2 (C-average), 3 (B-above average), and 4 (A-excellent).

Higher Mathematics Courses Taken in High School. From high school records for 9th through 12th grades, higher math courses (algebra 1, 2, and 3; algebra 2 honors; mathematical analysis; geometry; geometry honors; analytical geometry; trigonometry; calculus; advanced placement calculus; and advanced placement statistics) were counted, with heavier weightings given to "honors" courses. The score for the variable "higher mathematics courses taken" was obtained by adding the number of courses with a score of 1 for regular math courses. A second variable was established comparing the number of honors courses taken. Finally, a weighted combined point value of mathematics courses taken was determined by summing all courses taken and giving a score of 2 for those labeled as honors and advanced courses.

Procedures

The predictor variables of levels of block play (SES and IQ) were measured in the fall of 1982 by testing a group of 3- and 4-year-old preschoolers. The longitudinal effects were later examined and gender factored in after these same participants had completed high school. Their school records—at the elementary, middle, and high school levels—were obtained in 1998. During the preschool phase of data gathering, the participants were rated by a researcher with the use of Lunzer Five Point Play Scale (Lunzer, 1995); the researcher had been trained and had demonstrated an interjudgmental reliability of 94 percent. This scoring was done while the participants were engaged in block play on three different days in the natural classroom setting, without any facilitation from their teacher. Participants were simply instructed by the teacher at the beginning of the play session, "Do the best block play that you can do today, and use as many blocks as you can!" The researcher used the best of the three scores as the independent or predictor variable.

Because IQ has been determined to correlate to school achievement in mathematics (Aiken, 1976; Campbell & Ramey, 1995), and accounts for a large percentage of the variance in play research (Smilansky, 1968; Smilansky & Shefatya, 1990), the researcher also administered the McCarty Scales of Children's Abilities (McCarty, 1972) to obtain an IQ score. Since gender has also been shown to be correlated to various play abilities and mathematics (Casey, Pezaris, & Nuttal, 1992; Fennema & Sherman, 1978; Leder, 1985; Leder & Fennema, 1990; Meyer & Koehler, 1990), gender was established as a dichotomous variable. The dependent or outcome variables obtained from school cumulative records included: 1) results from the California Achievement Test, 2) the grades in mathematics courses, and 3) higher mathematics courses taken in high school.

Statistical Analysis. Using the SPSS (Statistical Package for Social Science), two statistical analyses were used in this study—hypotheses that state a relationship were tested with simple regression, while those requiring control for IQ and gender used multiple regression.

Results

The Elementary Grade Levels

Correlational analysis and regression techniques were used to determine the relationship between block play and mathematical achievement. The researchers' initial set of analyses addressed the

between-year interrelations among construction play with blocks, and their measures of mathematical achievement. The correlation coefficients are presented in Table 2. These analyses indicated that there were not significant correlations between measured block play and the students' 3rd-, 5th-, and 7th-grade standardized test scores. Similarly, there were no significant correlations between the measure of block play and the student's mathematics grades at the 3rd-, 5th-, and 7th-grade levels.

The second set of analyses addressed the researchers' hypotheses concerning the predictive relations between measures of children's block play and their mathematical achievement in 3rd, 5th, and 7th grade. Using hierarchical regression techniques, the analysis were designed to control contributions due to IQ and gender respectively. Because gender and intelligence have been related to mathematics achievement in previous research, they were used as a control variable in all analyses. A two-step hierarchical regression was performed for each of the mathematics achievement measures. These analyses were based on the assumption that the association between the variables of interest was linear. Furthermore, it was assumed that the conditional variance was equal and that the conditional values on the dependent variables were normally distributed. Examinations of the residuals revealed no apparent violation of these assumptions. Gender and IQ were entered as control variables at step one and measures of block play were entered at step two. Findings indicated that children's play with blocks reliably predicted mathematical achievement at the 7th-grade levels ($F = -3.78$, $p = .03$).

High School Level

Similar analyses were conducted to determine the relationship between block play and the participants' mathematical achievement at the high school level. For these analyses the researchers examined the predictive relationship between participants' block performance and 1) the number of higher mathematics courses taken in high school, 2) the number of honors classes taken, 3) participants' average high school mathematics grades, and 4) a weighted high school mathematics "points" score that was created to give more weighting to honors mathematics courses.

Analyses indicated that there was a significant relationship between preschool block performance and the number of higher mathematics courses taken, $F = 4.18$, $p = .02$. Similarly, there was a significant relationship between preschool block play and the number of honors courses taken, $F = 4.05$, $p = .02$. The relationship between the participants' high school mathematics grades also yielded a significant relationship, $F = 5.6$, $p = .01$. Finally, the relationship between block play performance and the mathematics "points" score was judged significant, $F = 4.6$, $p = .01$.

In summary, the researchers' hypotheses were supported to the extent that children's play with blocks reliably predicted mathematical achievement at the 7th-grade and high school levels. Thus, with controls for IQ and gender, preschool block performance accounted for nontrivial portions of variability.

Discussion

Block performance during the preschool years and the later variable of students' letter grades and mathematical achievement on standardized tests did not demon-

Table 2
Correlation Matrix of Grades 3, 5, 7: Mathematics and Blocks

	Math Standardized Test Score			Math Grade		
	Grade 3	Grade 5	Grade 7	Grade 3	Grade 5	Grade 7
Blocks	0.3158 (p=.101)	0.0296 (p=.452)	0.2785 (p=.105)	0.1374 (p=.313)	0.0665 (p=.384)	-0.1414 (.260)

strate significance at the 3rd- and 5th-grade levels. At the same time, no significance was found at 7th-grade level on teacher-awarded grades. A clear significance was found, however, for standardized testing at this same level. Also, since all other outcome variables at the middle school and high school levels—such as number of classes taken, number of honors classes taken, average mathematics grades, and a combined weighted value of all mathematics course taken—were all significant, the authors conclude that there is a statistical relationship between early block performance during preschool and achievement in mathematics, although not at the elementary school years, but rather at the later middle and high school levels. The question is raised as to why this same significance does not appear at the 3rd- and 5th-grade levels.

One possible answer could be that children near the age of 11, or the beginning of middle school, typically begin to acquire formal operational thinking (Piaget, 1977), which enables the child to reason in abstract terms and separate from the need to rely as heavily on concrete objects (Forman & Kuschner, 1984). From a Piagetian framework, the acquisition of knowledge is cumulative, drawing on the motor activities of the preoperational years and stages (like block play during the preschool school years and concrete use of objects during the concrete operational period during the elementary school years). Although a causal relationship was not established in this study, one may still hypothesize that those preschool age participants who demonstrated high levels of performance with block building were developing the basic underlying cognitive structures that would permit them to perform well in higher abstract mathematics, such as geometry, trigonometry, and calculus. This can been seen as early as the 7th grade on standardized tests of mathematics skills. In turn, grades awarded by teachers, and the standardized testing during the elementary years (in grades 3 and 5), only test minimum skills and memorization, and thus the researchers found no correlation between elementary mathematics and block performance during this preoperational period. This finding may suggest that the real and lasting effects cannot be demonstrated by academic measures during the elementary school years, but rather can be seen at the beginning of the middle school years. Support for this assertion can be found in the research literature (Schweinhart, Weikart, & Larner, 1986).

Follow-up studies on the effects of compensatory early preschool education demonstrate that the effects on these children, who were followed beginning in the 1st grade, were minimal and not found later in the elementary grades (Luzar, 1981). The findings shown here as to the lack of statistical significance at the elementary school level conforms to these previous studies; however, later findings at the middle school and high school levels suggest that earlier findings on the lasting effects of preschool experience on the students were premature. Only later can these effects be determined; namely, after students have obtained formal operational thinking, and when students study school subjects that require true higher-order thinking. Other researchers have found this latency effect (Anderson, 1992; Campbell & Ramey, 1995; Lee et al., 1990). These findings would support the inclusion of blocks and block play in the play curriculum of preschool age children.

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