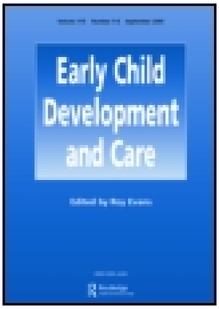

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A Longitudinal Study of the Predictive Relations Among Construction Play and Mathematical Achievement

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A Longitudinal Study of the Predictive Relations Among Construction Play and Mathematical Achievement

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This longitudinal study began in 1982 with 37 four year old children who attended the same child care center for at least one year. The participants were assessed on their construction play products of blocks, Legos, and carpentry using the *Lunzer Five Point Play Scale*. An IQ score was obtained using *The McCarthy Scales of Children's Mental Abilities*. Gender was also used as a control variable.

In 1998, 27 of these participants were found and standardized test scores in mathematics for grades 3, 5, 7, and high school were correlated with play scores. The *California Acheivement Test* as well as high school higher mathematics classes and honors format classes were noted.

Results showed that grades 3 and 5 had little significance found between a participant's play performance and mathematical achievement. At grade 7 and in high school each area of construction play and standardized test scores were found to be significant.

Key words: Play, construction play, mathematical thinking, blocks, legos, capentry

The effects of play on various aspects of children's development has been documented by many researchers (Athey, 1984; Pellegrini, 1985). The literature suggests that play is related to children's cognitive, social, emotional, and physical development. For example, in the area of language development, researchers have noted positive relations between symbolic play and literate behavior (Cazden 1971; Pellegrini, 1991). Similarly, in the area of social development, a relationship between social perspective taking and the social interaction characteristics of children's peer interactions has been established (Rubin, 1980). Aspects of children's play have also been correlated with school related performance in areas such as reading and writing (Pelligrini, 1980). Fewer studies, however, have examined the effects of play on children's mathematical thinking. This study examines the relationship between children's construction play and their mathematical competence. Drawing on Piaget's (1962) theory of cognitive development, the study tests the hypothesis that the complexity of children's construction play should predict future school — related mathematical performance.

It is well established that children's school mathematical competence varies as a function of socioeconomic status (SES) and that this is detected in the preschool years on informal tasks (Saxe, Guberman & Gearhart, 1987; Yando, Seitz & Zigler, 1979). Furthermore, this trend continues through the elementary grades and beyond. One proposed reason for this trend concerns the contextual difference between mathematics in school and everyday mathematics. These differences can be traced to aspects of both the physical and social settings that compose young children's mathematical experiences (Pelligrini & Stanic, 1993). At this micro level, the materials (e.g., blocks, board games, carpentry), people (e.g., siblings, peers, teachers), and processes (e.g., direct instruction by mother, solitary interaction with materials) potentially influence the development of mathematical competence.

The preschool is one of the contexts where young children engage in informal mathematics tasks and therefore, gain early mathematical experiences, In this setting a significant amount of informal mathematics tasks can occur during children's play activities. Construction play, for example, offers children an opportunity to classify, measure, order, count, use fractions, and be aware of depth, width, length, symmetry, shape, and space (Hirsch, 1996). These are all mathematical concepts that children will use in later school years. It follows that there could be a connection between these informal activities and the child's subsequent success in learning about mathematics in school. In short, children's construction play could influence the development of their mathematical knowledge.

CONSTRUCTION PLAY

Construction play is the most frequently observed form of play that is seen in three and four year old children. When children engage in construction play they use materials with a predetermined shape and size to represent their ideas. This type of play, referred to as structured construction play, allows children to use materials such as blocks and Legos to create a product that represents something else. Typically, children will use materials to represent those things which are familiar to them.

A related type of play is reconstruction construction play. This is a form of play where the materials begin in a particular form but are rearranged to create another form (Wolfgang & Wolfgang, 1992). Carpentry, a form of reconstruction construction play, allows children to select wood pieces, saw them into the desired size and shape, and then use tools such as a hammer and nails to recreate a new structure.

Construction Play and Mathematical Thinking

Piaget (1962) differentiated between learning physical knowledge and learning logico-mathematical knowledge. Physical knowledge is derived from activities with objects that allow children to make generalizations about their physical properties. Logico-mathematical knowledge includes concepts such as classification, seriation, temporal, and spatial relations, and number. Piaget (1962) proposed that logico-mathematical knowledge, or knowledge about the relationships between objects, is constructed as children reflect on the relationships between actions or objects. That is, children construct their own understanding through an ongoing process of activity that makes possible personal transformation of knowledge.

During construction play with blocks, children construct knowledge, not from the physical experience itself, but rather from reflecting on it. For example, a child might compare the size of two blocks, or perhaps examine the relative lengths of several blocks. Construction play represents a context where children act on objects thereby constructing logico-mathematical knowledge. Thus, we propose that construction play serves a developmental function because it shares structural or behavioral characteristics with specific developmental outcome measures in the area of mathematics.

Several researchers suggest that concepts such as classification and seriation can be learned during block play (e.g., Hirsch, 1996) and that children's abilities in these areas will predict future mathematical achievement. Construction play offers young children an opportunity to learn mathematics and numbers. This form of play allows children to practice the use of complex skills and the ability to mentally visualize relationships. These mental manipulations are similar to those used in algebraic equations and geometric proofs when the child is in later school years (Henniger, 1987). For example, children constructing a fort with blocks will have multiple opportunities to practice mathematics related skills. They must select the blocks of different sizes and shapes, measure and compare length, width, and height. They compare surface volume and area. Block clean up involves classifying by comparing like and different shapes and sizes, and one to one correspondence (Henniger, 1987). Furthermore, by playing with blocks, children are playing with spatial configurations (Reifel, 1983). Spatial science is an important aspect of geometry and mathematical achievement (Casey, Pezaris & Nuttal 1992).

During construction play children are receiving the basis of science of quantity (arithmetic) and shape (geometry) by manipulating different shaped materials, counting, classifying, seriating, using one to one correspondence, and making patterns. Similarly, carpentry with preschool children can enhance the development of physical, cognitive, and social skill (Skeen, Garner & Cartwright, 1984). Carpentry, like block play, enables children to solve and use information they have obtained through exploring and experimenting with the materials (Cartwright, 1971). In short, in doing construction play activities, children are doing mathematics. It follows that children's construction play should predict children's mathematical achievement during later school years. Surprisingly, however, there is a paucity of longitudinal research on the predictive relations between construction play and measures of mathematical competence and achievement. To our knowledge, the question of the relationship between play and mathematics has not been addressed in previous longitudinal studies.

Finally, gender could also be relevant in the study of young children's construction play and mathematics. It is known that boys tend to play with a wider variety of toys, particularly those that are spatial in nature such as blocks and Legos (Tracy, 1987). In contrast, girls tend to be oriented toward domestic pursuits and do not engage as often in activities involving manipulation, construction, or movement. It is also known that boys tend to exhibit superior spatial skills (Brosnan, 1998) and maintain greater science and mathematics achievement scores than girls (Tracy, 1987). A reasonable expectation, therefore, is that there would be gender differences in the levels of construction play as well as in future school related mathematics performance. The purpose of this study was to determine the relationship between preschool children's construction play (blocks, Legos and carpentry), and mathematical achievement during later school years. It was hypothesized that measures of children's adaptiveness in using blocks, Legos, and carpentry as four year olds, as well as the complexity of their construction play, should predict future mathematical achievement. This prediction is based on the premise that construction play with structured materials (blocks, Legos and carpentry) and mathematics share structural and behavioral characteristics.

METHOD

Participants

The participants were an intact group of 37 children who, in 1982, attended a play oriented child care program. All of the participants had attended the program for a minimum of one year. The age of the group at the beginning of the year ranged from 3 years 10 months to 4 years and 11 months. These participants were contacted in 1998 and 27 (13 males and 14 females) agreed to allow researchers to collect data from their school records. According to school records 85% of the participants were Caucasian and 15% were African American. Of these 27 participants, 22 had attended public schools, 4 had been enrolled in a Laboratory/University school, and 1 had attended a private school.

Procedures

All of the participants attended an early childhood program for ages 2 months through Kindergarten. The center provided a variety of play opportunities on a daily basis including sensorimotor, symbolic, and construction play. Materials were available to allow children to engage in both structured and reconstruction construction play.

The participants were assessed in their play using the *Lunzer Five Point Play Scale* in several different kinds of play including blocks, Legos, and carpentry. This rating scale was designed to rate the player on adaptiveness in using the materials and the integration of behavior in play or the complexity of play. The participants were rated on a five point scale where a score of one means that the material is used in a highly insightful manner, and adapted to a concept which clearly transcends it (Hulme & Lunzer, 1966; Lunzer, 1955).

The scale was administered by four of the child care center staff who had been trained in the use of the instrument. All of the students were observed in each of the three construction play contexts: blocks, Legos, and carpentry. For block play, the students were told to "build whatever you would like, use as many blocks as you like, and spend as much time as you need." The observer then noted what was said, sketched the structure that was built, counted the number of blocks that were used, and noted how many of each kind were used.

Then, using the *Lunzer Five Point Play Scale*, this information was reviewed and rated by two child care center staff members. Similar procedures were used for measuring children's play with Legos. Again, students were told to use as many materials as they wanted, and to take as much time as they needed. The students were provided with standard sized Legos and allowed to build on the table or on the floor.

For measuring children's play with carpentry the students were provided with a variety of pieces of wood, nails, safety goggles, hammers, bottle caps from soft drink bottles, milk jug caps, and markers for drawing. The students were told to build whatever they choose to make and to take as much time as necessary, and use as many materials as they needed. Again, ratings were based on the same procedures. For all three measures, inter rater reliability was within an acceptable range (.94).

In addition, an IQ score was obtained using the *McCarthy Scales of Children's Mental Abilities*. This test was designed to measure young children's intellectual abilities and their strengths and weaknesses in other skills. The instrument consists of a battery of 18 tests grouped into 6 scales. These scales include measures in the verbal, perceptual performance, quantitative, memory, and motor abilities of children ages 2.5 to 8.5 years. A general cognitive score is obtained from the sum of the verbal, perceptual performance, and quantitative scales. The general cognitive index has a mean of 100 with a standard deviation of 16 which are the same parameters used to define intelligence quotients in other mental tests. The instrument was administered individually to the participants at the child care center by a research assistant.

Student's scores in mathematics on the *California Achievement Test* were obtained from school records when the participants were in grades 3, 5, and 7. The National Percentile score in the mathematics total section were used for the purpose of this study. The participants' high school mathematics courses and grades were counted from school records. The number of higher mathematics classes taken by the participants in grade 9, 10, 11, and 12 were counted. Some courses are offered as "honors classes" as well as regular format. A rating scale was therefore developed so that honors classes could be weighted heavier than regular classes.

RESULTS

Descriptive statistics for the measure of construction play are presented in Table 1.

Our initial set of analyses addressed the between year interrelations among construction play with blocks, Legos, and carpentry and our measures of math-

Table 1 Means and Standard Deviations for Measures of Preschool Students' Construction Play with Blocks, Legos and Carpentry

PlayForm	*n*	*Mean*	*Standard Deviation*
Block	27	11.77	1.9
Legos	27	15.15	2.39
Carpentry	27	14.88	3.13

Table 2 Correlations Between Measures of Children's Construction Play and Mathematical Achievement

	Grade 3 CAT	*Grade 5 CAT*	*Grade 7 CAT*	*Higher Mathematics Classes*	*Average Math Grade*	*Honors Classes*
Legos	.08	.34*	.07	.58***	.37**	.52**
Blocks	.31*	.03	.28*	.11	.08	.22*
Carpentry	.23	.07	.31 *	.35**	.41 **	.38**

*$p < .10$; **$p < .05$; ***$p < .01$

ematical achievement. The significant correlation coefficients are presented in Table 2.

The second set of analyses addressed our hypotheses concerning the predictive relations between measures of children's play with blocks, Legos, and carpentry and their mathematical achievement in grades 3, 5, 7, and high school. Using hierarchical regression techniques, the analyses were designed to control contributions due to IQ score and gender. Because gender and intelligence have been related to mathematics achievement in previous research, they were used as control variables in the 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 variances were equal and that the conditional values of the dependent variables were normally distributed. Examinations of the residuals revealed no apparent violation of these assumptions. Additionally, results of diagnostic tests (Cook's distance, DFIT, DFBETA) revealed no influential outliers. Gender and IQ scores were entered as control variables at step 1, and measures of construction play (blocks, Legos, and carpentry) were entered at step 2. These results are reported in Tables 3 and 4.

For descriptive purposes, standardized betas were examined for the final regression equations to identify which type of construction play activity contributed unique information to the mathematics achievement scores. These are presented in the last column of Tables 3 and 4.

Our hypotheses were supported to the extent that children's play with blocks predicted mathematical achievement in grade 7 and high school. Similarly, both

Table 3 Summary of Hierarchical Multiple Regression Assessing Higher-Order Relations on Mathematics Achievement Scores

Step	*Variables*	R^2	R^2 *Change*	*F Change*	*Final Beta*
Mathematics Grade 3					
1.	Control Variable:	0.2	0.22	1.7	—
	IQ	2	—	—	0.48
	Gender	—	—	—	0.05
2.	Play Variables:	0.2	0.05	0.19	—
	Blocks	7	—	—	0.31
	Legos	—	—	—	0.15
	Carpentry	—	—	—	0.20
Mathematics Grade 5					
1.	Control Variables:	0.2	0.25	2.14	—
	IQ	5	—	—	0.48
	Gender	—	—	—	0.08
2.	Play Variables:	0.7	0.29	2.03	—
	Blocks	3	—	—	0.23
	Legos	—	—	—	0.43
	Carpentry	—	—	—	0.76
Mathematics Grade 7					
1.	Control Variables:	0.4	0.44	5.86	—
	IQ	4	—	—	0.65
	Gender	—	—	—	0.06
2.	Play Variables:	0.5	.13	1.16	—
	Blocks	7	—	—	0.06
	Legos	—	—	—	0.33
	Carpentry	—	—	—	0.37

play with Legos and carpentry predicted children's grade 7 and high school mathematical achievement scores as well the number of higher mathematics courses taken.

DISCUSSION

This longitudinal study supports the proposition that children's construction play involves complex mathematical processes that can influence the development of logico-mathematical knowledge. This is supported by the fact that measures of children's play using blocks, Legos, and carpentry predicted children's mathematical achievement in grade 7 and beyond. These findings suggest that similarities exist between the processes involved in construction play and mathematical behavior.

Table 4 Summary of Hierarchical Multiple Regression Assessing Higher-Order Relations on Mathematics Achievement Scores

Step	*Variables*	R^2	R^2 *Change*	*F Change*	*Final Beta*
Number of High School Classes					
1.	Control Variables:	0.44	0.44	6.55	—
	IQ	—	—	—	0.38
	Gender	—	—	—	0.45
2.	Play Variable:	0.53	0.09	3.2	—
	Blocks	—	—	—	0.03
	Legos	—	—	—	0.34
	Carpentry	—	—	—	0.15
Honors Classes					
1.	Control Variables:	0.38	0.38	5.28	—
	IQ	—	—	—	0.45
	Gender	—	—	—	0.24
2.	Play Variables:	0.46	0.08	2.37	—
	Blocks	—	—	—	0.22
	Legos	—	—	—	0.19
	Carpentry	—	—	—	0.01
Average Mathematics Grade					
1.	Control Variables:	0.44	0.44	6.8	—
	IQ	—	—	—	0.44
	Gender	—	—	—	0.39
2.	Play Variable:	0.53	0.09	3.16	—
	Blocks	—	—	—	0.12
	Legos	—	—	—	0.29
	Carpentry	—	—	—	0.10

Thus, preschool construction play experiences seem to result in different school related trajectories. These findings are consistent with findings by Miller and Bizzell (1983) offering evidence of effects at the middle school level resulting from pre kindergarten experiences. The significance of construction play and mathematical achievement in participants at age 12 and above is best explained from a Piagetian perspective. Children at this age are in Piaget's formal operational stage of thinking. The cumulative nature of Piaget's stages (Forman & Kuschner, 1983) mean that the experiences that children have during preschool years have an effect on their formal operational thought during their adolescent years. Our findings are also consistent with other studies that offer insights into how preschool experiences influence later educational successes (Schweinhart & Weikart, 1986; Karnes *et al.*, 1983).

There were two independent control variables used in this research, gender and IQ score. The impact of these on the regression model were found by examining the beta weights and checking for significance at the .05 alpha level. The significance found in the relationship between IQ score and grade 7 standardized test score and high school mathematics is not surprising. One would expect that participants who have chosen to take higher mathematics classes have the possibility of having higher IQ scores. The regression equations which showed the significant impact of gender on the overall model were carpentry and blocks and higher mathematics classes. This is consistent with the review of literature which shows that most gender differences in mathematical abilities do not become apparent until the high school level (Leder, 1985). Why there are not more equations that show significance is somewhat surprising. A possible explanation could be that the participants involved in this study where in an environment where there were expectations that they must be involved in all areas of play. Each child had specific days when they were expected to participate in blocks, Legos, and carpentry regardless of gender.

The teaching of mathematics in our schools tends to be an endless sequence of memorizing facts and procedures that make little sense to students (Battista, 1999). Battista says that as children enter school many enjoy mathematics and solve problems that make sense to them. Unfortunately, most exit school apprehensive and not confident in their ability to do mathematical tasks (Battista, 1999). Battista says that mathematics miseducation seriously handicaps our nation in competitiveness in the world. Bredecamp (1988), reminds early childhood educators that the way mathematics is taught in the early years, shapes the child's perception of their mathematical competence. The results of the current study lend support to the practice of using structured play materials such as blocks, Legos, and carpentry with young children. During construction play, children are able to plan, problem solve, represent objects, and obtain knowledge of relationships with objects. It follows that young children should be given adequate time to play and be provided with appropriate construction props. When young children use concrete materials in this way they are provided with a solid base on which to build their mathematical thinking.

Clearly, establishing a causal relationship between construction play and mathematical achievement is beyond the scope of this study. Further research is therefore recommended to validate these initial findings.

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References

Athey, I. (1984). Contributions of play to development. In T.D. Yawkey and A.D. Pellegrini (Eds.) *Child's Play: Developmental and Applied.* Hillsdale, N.J.: Erlbaum.

Battista, M. (1999). The mathematical miseducation of America's youth: Ignoring research and scientific study in education. *Phi Delta Kappan,* **80**, 424–433.

Bredecamp, S. (Ed.) (1988). *Developmentally appropriate practice in early childhood programs.* Washington, D.C.: NAEYC.

Brosnan, M.J. (19??). Spatial ability in children's play with Lego blocks. *Perceptual and Motor Skills,* **87**, 19–28.

Cartwright, S. (1971). *Trips and blocks: A study of five year-old learning.* Masters Thesis, Bank Street College of Education, New York.

Casey, M.B., Pezaris, E. and Nuttall, R.L. (1992). Spatial ability as a predictor of math achievement: The importance of sex and handedness patterns. *Neuropsychologia,* **30**, 35–45.

Cazden, C. (1974) Play with language and metalinguistic awareness: One dimension of language experience. *The Urban Review,* **1**, 23–29.

Forman, G. and Kuschner, D. (1983). *The child's construction of knowledge: Piaget for teaching children.* Washington, D.C.: NAEYC.

Henniger, M. (1987). Learning mathematics and science through play. *Childhood Education,* **63**, 167–171.

Hirsch, E. (1996). *The Block Book.* Washington, D.C.: NAEYC.

Hulme, I. and Lunzer, E.A. (1966). Play, language, and reasoning in abnormal children. *Journal of Child Psychological Psychiatry,* **7**, 107.

Karnes, M., Schwendel, A. and Williams, M. (1983). A comparison of five approaches for educating young children from low income homes. In Consortium for Longitudinal Studies Staff (Eds.), *As the twig is bent...Lasting effects of preschool programs* (pp.133–169). Hillsdale, N.J.: Erlbaum.

Leder, G. (1985). Gender differences in mathematics: An overview. In E. Fennema (Ed.) Explaining sex-related differences in mathematics: Theoretical models (pp.304–311). *Educational Studies in Mathematics,* **16**, 303–320.

Liedtke, W. (1995). Developing spatial abilities in the early grades. *Teaching Children Mathematics,* **21**, 12–18.

Lunzer, E.A. (1955). *Studies in the development of play behavior in young children between the ages of two and six.* Unpublished doctoral dissertation, Birmingham University, London.

McCarthy, D. (1972). *McCarthy scales of children's mental abilities.* New York: The Psychological Corporation.

Miller, L. and Bizzell, R. (1983). Long term effects of four preschools: Sixth, seventh, and eighth grades. *Child Development,* **54**, 727–741.

Pasnak, R., McCutchen, Holt and Campbell. (1991). Cognitive and Achievement Gains for kindergartners Instructed in Piagetian Operations. *Journal of Educational Research,* **85**, 5–13.

Pasnak, R. Martin, Madden, Malabonga and Holt. (1996) Persistence of Gains from Instruction in Classification, Seriation, and conservation. *Journal of Educational Research,* **90**, 87–92.

Pellegrini, A.D. (1980). The relationship between kindergartners' play and achievement in pre reading, language, and writing. *Psychology in the Schools,* **17**, 530–535.

Pellegrini, A.D. (1985). The relationship between symbolic play and literate behavior: A review and critique of the empirical literature. *Review of Educational Research,* **55**(1), 107–121.

Pellegrini, A.D. (1991). A longitudinal study of the predictive relations among symbolic play, linguistic verbs, and early literacy. *Research in the Teaching of English,* **25**, 219–235.

Pellegrini, A.D. and Stanic, G.M.A. (1993). Locating children's mathematical competence: Application of the developmental niche. *Journal of Applied Developmental Psychology,* **14**, 501–520.

Piaget, J. (1962). *The language and thought of the child,* New York: Harcourt Brace.

Piaget, J. (1962). *Plays, dreams, and imitation in childhood.* New York: Norton.

Reifel, S. (1983). *Spatial representation in block construction.* Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Rubin, K. (1980). Fantasy play: It's role in the development of social skills and social cognition. In K. Rubin (Eds.), *Children's Play.* San Francisco: Jossey-Bass.

Saxe, G., Guberman, S. and Gearhart, M. (1987). Social processes in early number development. *Monographs of the Society for Research in Child Development*, **52** (Serial No. 216).

Schweinhart, L., Weikert, D. and Larner, M. (1986). Consequences of three curriculum models through age 15. *Early Childhood Research Quarterly*, **1**, 15–45.

Skeen, P., Garner, A. and Cartwright, S. (1993). *Woodworking for young children*. Washington, D C: NAEYC.

Tracey, D.M. (1987). Toys, spatial ability, and science and mathematics achievement: Are they related? *Sex Roles*, **17**, 115–138.

Wolfgang, C. and Wolfgang, M. (1992). *School for young children*. Boston: Allyn and Bacon.

Yando, R. Seitz, V. and Zeigler, E. (1979). *Intellectual and personality characteristics of children*. Hillsdale, N.J.: Erlbaum.