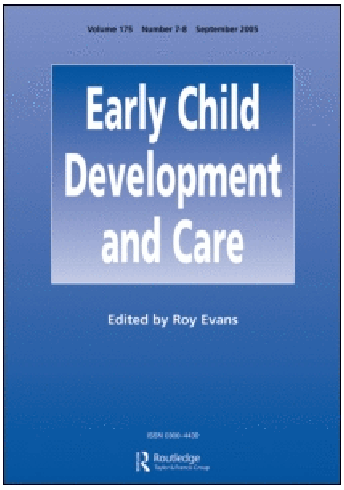

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The relationship between preschool block play and reading and maths abilities in early elementary school: a longitudinal study of children with and without disabilities

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The purpose of this study was to explore the predictive relationship between the level of symbolic representation in block constructions of preschoolers and reading and mathematics abilities and rate of growth in early elementary school for children with and without disabilities. Fifty-one children participated, 22 of whom had identified disabilities. No predictive relationship between representational level of block constructions and maths abilities was found. However, growth curve analysis documented that preschoolers, who had higher levels of representation in their block constructions, had higher reading abilities and a faster rate of growth in reading abilities in the early elementary years. This predictive relationship held true for children with and without disabilities. Findings are discussed in relation to the importance of early experiences that are physically and socially organised to provide young children with the foundation for later learning.

Keywords: block play; construction play; early academics; emergent literacy; mathematics; disabilities

The positive effects of children's play on development in the preschool years have been well documented. Socio-dramatic play has been the focus of the majority of this research. Studies have demonstrated that socio-dramatic play enhances problem-solving abilities, cognitive functioning, representational competence and divergent thinking (e.g. Cheyne & Rubin, 1983; Pederson, Rook-Green, & Elder, 1981; Pepler & Ross, 1981; Saltz, Dixon, & Johnson, 1977). Socio-dramatic play has also been linked to literacy-related skills (e.g. Bergen, 2002), mathematical readiness (e.g. Yawkey, 1981), language development (e.g. Levy, Schaefer, & Phelps, 1986; Levy, Wolfgang, & Koorland, 1992) and social participation (e.g. Smith, Dalgleish, & Herzmark, 1981).

Construction play has been studied far less frequently than socio-dramatic play. However, one type of structured construction play that may contribute in a unique way to a child's development is block play. As children handle blocks, they become mentally active, learning to interpret and process sensory information. Block play can promote problem-solving skills and logical thinking, increase physical and logical

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mathematical knowledge and provide opportunities to learn early mathematics skills such as counting, sorting, classifying, identifying shapes, and understanding equivalencies and part-to-whole relationships (Gelfer & Perkins, 1988; Piaget, 1962; Wellhousen & Kieff, 2001; Williams & Kamii, 1986). Block play may also contribute to language learning (Cohen & Uhry, 2007). Isbell and Raines (1991) found that language fluency and the variety of language structures were actually greater during block play than during housekeeping socio-dramatic play. Language can also improve through the socio-dramatic play that becomes part of block play when the appropriate props are available (Phelps & Hanline, 1999). Further, blocks are representational and serve as an introduction to symbols, supporting emergent literacy learning in a developmentally appropriate context (Stroud, 1995).

Thus, block play not only promotes early development, but may also provide foundational experiences for later mathematical and literacy learning. However, only two studies have related construction play abilities in preschool to later academic learning (Stannard, Wolfgang, Jones, & Phelps, 2001; Wolfgang, Stannard, & Jones, 2001). These studies reported that children's play with blocks in the preschool years, while not correlated with mathematics achievement in third and fifth grades, was positively correlated with standardised mathematics test scores and grades in seventh grade and high school. That is, greater constructive play abilities (including block play) in preschool predicted higher mathematical achievement in middle and high school.

These two studies were conducted using archival data gathered at the same preschool at which the current study was conducted. However, the present study differs from those of Stannard et al. (2001) and Wolfgang et al. (2001) in that it conducted follow-up measures of children at a younger age (five to eight years), implemented rigorous experimental control, observed children directly, assessed both reading and maths skills in follow-up measures and included children with disabilities.

Therefore, the purpose of the present study was to explore the predictive relationship between the level of symbolic representation in preschoolers' block constructions and reading and mathematics abilities and rate of growth in early elementary grades for children with and without disabilities. A further purpose of the study was to determine if rates of growth and academic achievement in early elementary years differed between children with and without disabilities.

Methods

This study reports the findings of one component of research and model demonstration projects funded by the US Department of Education[1]. The projects involved gathering longitudinal data on play behaviours during the preschool years, and then conducting academic assessments following the children's transition to kindergarten. The children in the present study were selected from a total sample of 117 children because they participated in adequate numbers of block play observations (minimum of eight) and follow-up academic testing for data analysis (minimum of two).

Participants

Fifty-one children participated in this study, 22 of whom were receiving special education services from the local school district. Children received special education

Table 1. Description of participants.

Child characteristics	With disabilities (n = 22)	Without disabilities (n = 29)
Sex, n (%)		
Male	11 (50)	17 (59)
Female	11 (50)	12 (41)
Developmental quotient on BDI		
Mean	74.10	104.99
Standard deviation	19.62	8.58
Ethnicity, n (%)		
Caucasian	14 (64)	24 (83)
African-American	8 (36)	4 (14)
Hispanic	0 (0)	0 (0)
Other	0 (0)	1 (3)

services because of developmental delay/disability resulting from Down syndrome, prematurity, autism spectrum disorder, physical disabilities and speech/language disorders. Twenty-eight of the 51 children with and without disabilities combined were male and 23 were female. Table 1 summarises the demographic characteristics of the participating children. The majority were Caucasian.

The Batelle Developmental Inventory (BDI) (Newborg, Stock, Wnek, Guidubaldi, & Svinicki, 1984) was administered by a teacher in the preschool within a week of each child's initial observation in block play. The BDI is a standardised, individually administered assessment battery of developmental skills in children from birth to eight years. It consists of 341 test items grouped into five domains: personal-social, adaptive, motor, communication and cognitive. The BDI was standardised on 800 U.S. children representative of all areas of the country. Test-retest reliability is .99 for the BDI total score at ages 6–11, 12–17, 24–35 and 36–47 months and .98 for 0–5 and 18–23 months. Criterion-referenced validity correlations on the BDI total score with the DASI, Stanford-Binet, Wisc-R, Vineland and PPVT range from .41 to .94.

Children with disabilities had significantly lower overall age equivalents on the BDI ($p < .00$). All children must have performed at a minimum of 6 months on the sub-domain muscle control and 12 months on the sub-domain fine muscle of the motor domain of the BDI. In this way, the ability to manipulate blocks was assured. In addition, the special education teacher confirmed the appropriateness of the block construction scale for each participant with disabilities.

Setting and materials

The study took place in an inclusive child care programme that has included children with disabilities since its inception over 38 years ago. The programme has been continuously nationally accredited from 1989 to 2007. The preschool programme provides services to 120 children aged eight weeks through kindergarten. Programmes for infants and toddlers are located in a building separate from the preschool and kindergarten programmes.

Block construction data were collected in the block centre of the preschool, a space approximately 9.1 m x 15.2 m, separated from other areas of the room by shelves filled with over 3000 blocks, books about construction and micro-dramatic play props.

The blocks are arranged on the shelves according to their shape and in descending order according to size from left to right. Books with pictures of skyscrapers, bridges, etc., are available to the children. Pieces of different coloured plywood (approximately 0.9 m x 1.2 m) of various shapes on which the children build are spaced on the floor approximately 0.9 m apart.

Children participated in block play once a week for 90 minutes in a consistent play group of 10 children (no more than two children with disabilities per group) and the same adult. During the first 10 minutes, the teacher conducted an introduction. The teacher either (1) chose a block shape, discussed its geometric properties, showed pictures of constructions that use that shape and assisted the children to locate that shape throughout the classroom; (2) read a book about construction; or (3) led gross motor activities centred around the plywood markers. The adult then asked the children to find a space in which to play and suggested they use all the blocks they wanted to build whatever they chose. When children completed their block construction, they were encouraged to add play props to support symbolic play and to invite friends to play. This block centre and other areas with unit blocks were available to the children during other times during each day. Additional information about the structure and management of the block centre is provided in Phelps and Hanline (1999).

Design and procedure

Procedures for block construction data collection

Preschool data were collected four times per year (spaced approximately three months apart) by research assistants who were Master's degree students in early childhood special education or in early childhood education. During this time, the children built their block constructions independently, and the adult in the block centre did not initiate interactions with the children, but did respond to children's initiations. When children indicated they had completed their constructions, the block constructions were photographed for data analysis. Detailed information about the collection of these data can be found in Hanline, Milton, and Phelps (2002).

Procedures for follow-up academic testing

Parents of preschoolers from whom block construction data were collected were contacted each year after the participants had made the transition to elementary school. Consenting parents were asked for permission to have academic assessments administered to their children. Children were assessed individually in a quiet administration building of the preschool in June or July. Parental contact and child testing were done by a public school teacher holding a BS degree in special education.

Dependent variables

To assess the complexity of children's preschool block constructions, the photograph of each child's block construction was scored according to a 19-point block construction scale (Phelps & Hanline, 1999). The scale (Table 2) is based on the work of Guanella (1934) and Reifel (1982, 1984). The coding system shows a developmental

Table 2. Block construction scoring scale.

Score	Description of block use/construction
Non-construction use of blocks	
1	No constructions
	Child investigates physical properties of blocks by engaging in noise-making, transportation, motion and bodily contact manipulations. Child attempts to engage in social interactions using blocks
Linear constructions	
2	Vertical linear arrangement
	Child piles or stacks block on top of each other
3	Horizontal linear arrangement
	Child places blocks side by side or end to end in a row
Bidimensional/areal constructions	
4	Vertical areal arrangement
	Child constructs adjoining piles of blocks and/or superimposes row on row
5	Horizontal areal arrangement
	Child combines rows of blocks in a horizontal area
Tridimensional constructions	
6	Enclosed vertical space
	Child places two blocks parallel and spans the space between them with a block; forms an arch or bridge
7	Enclosed horizontal space
	Child makes square-like shapes out of four or more blocks
8	Solid tridimensional use of blocks
	Child makes a flooring out of blocks and superimposes one or more additional layers of blocks
9	Enclosed tridimensional space
	Child roofs horizontal enclosure and creates a tridimensional enclosed space
10	Elaborations/combinations of many construction forms
	Child uses various combinations of linear, bidimensional/areal and tridimensional constructions
Representational play	
11	Naming begins
	Child names individual blocks in constructions as ‘things’; block constructions/ block shapes may or may not resemble the ‘thing’ they are supposed to represent
12	One construction, one name
	Child names an entire block construction as a ‘thing’; one construction represents one ‘thing‘
13	Block ‘forms’ are named
	Child names block ‘forms’ in a construction as representing ‘things’. For example, a particular block in a structure representing a hospital might be labelled ‘the door’
14	Separated objects are named
	Child builds constructions that include separated objects; separated objects are named. For example, a single block that is separated from a house structure (built from many blocks) might be labelled a ‘tree’

Table 2. (*Continued*).

Score	Description of block use/construction
15	Interior space represented
	Child builds constructions that have interior space represented; interior space is not totally formed
16	Interior objects placed in the exterior
	Child builds constructions with enclosures that represent interior and exterior space; interior objects are placed outside the construction
17	Accurate representation of interior and exterior space
	Child builds constructions with enclosures that represent interior and exterior space; inside and outside objects are separated appropriately
18	Constructions built to scale
	Child builds constructions with block 'forms' separated; some sense of scale in the construction
19	Complex configurations
	Child builds a complex configuration that includes interior space, landmarks, routes and a sense of scale

progression of children's use of blocks from non-construction to linear constructions to bidimensional constructions to tridimensional constructions and to representational play with blocks. The scale reflects a child's growing understanding of representation and spatial relationships and topological and geometrical knowledge. The results of a growth curve analysis reported in a previous study (Hanline et al., 2002) documented that children's scores increased as their chronological age increased, providing content validity to this measure.

Three tests of academic skills were selected because of their excellent reliability and validity coefficients, ease of administration and appropriateness for use with young children. In addition, the norming sample of each test included children with disabilities. The instruments used were:

(1) *Test of Early Mathematics Ability (TEMA-2)*[2] (Ginsburg & Baroody, 1990). The *TEMA-2* measures the mathematics performance of children 0–3 to 8–11 years. The test measures concepts and skills in the following domains: numbering skills, number comparison facility, numeral literacy, mastery of number facts, calculation skills and understanding of concepts. Results are reported in standard score (M = 100; SD = 15) and percentile rank.
(2) *Test of Early Reading Ability (TERA-2)* (Reid, Hresko, & Hammill, 1989). The *TERA-2* measures the actual reading ability (rather than reading readiness) of young children 0–3 to 9–11 years. Performance is reported as a standard score (M = 100; SD = 15), percentile or normal curve equivalent.

Data analysis

Hierarchical linear modelling (HLM) growth curve analysis (Raudenbush & Bryk, 2002) was used to explore the predictive relationship between the level of symbolic representation in preschool block constructions and reading and mathematics abilities and rate of growth in early elementary grades and to determine if rates of growth and academic achievement differed between children with and without disabilities. In

HLM growth curve analysis, two analyses are conducted – one at the level of repeated observations of individual children and second at the level of children's characteristics (such as disability status or gender) predicting their rate of growth. These two analyses are reported as Level 1 and Level 2 analyses, respectively.

In Level 1 analysis, using ordinary least squares regression analysis, each child's reading and maths score is regressed against his/her chronological age in two separate analyses. The regression coefficient (b) for each child can be interpreted as the growth rate for that child, i.e. the increase (or decrease) in reading and maths scores per month.

The second parameter, the intercept for each child, is handled differently than in typical regression analysis. The typical treatment of the intercept in regression analysis is to estimate the point at which the regression line crosses the y-axis, i.e. the score on the dependent variable when x, the independent variable, is equal to zero. However, in the case of growth in maths and reading scores over age, the intercept when x is equal to zero would be interpreted as the estimated maths or reading score when a child is zero years old. Not only would this be a non-sensical construct, but is also an extrapolation below the range of the data collected. Instead, in growth curve analysis, the intercept is typically estimated (i.e. centred) at a substantively meaningful level of the independent variable. In this analysis, we provided an estimate of each child's maths and reading score at eight years of age.

In Level 2 analysis, these two parameters, the regression coefficient (growth rate) and intercept (estimated score at eight years), are themselves used as dependent variables that can be functions of other independent variables. Such an analysis is often referred to as using 'slopes as outcomes'. Thus, the correlates of growth rates among children, or of their scores at a given age, can be investigated. In this study, we are able to determine the differences in growth rates between children with and without disabilities, and between estimated maths and reading scores at age eight between children with and without disabilities. HLM is designed to test the statistical significance of these differences between mean growth rates and score levels of these two groups. In addition, gender was included in the Level 2 model as research has reported conflicting results about sex differences in maths abilities (reviewed in Hyde, Fennema, & Lamon, 1990).

HLM growth curve analysis typically proceeds in three steps. First, using a combination of theory and visual data inspection, the form of the growth curve for individuals is specified. Here it is determined whether to use linear or non-linear growth curve models. Second, in the Level 1 analysis, slopes and intercepts are computed for each individual according to the specified curve, and the array of slopes and intercepts is inspected to determine whether there is sufficient variability among individuals to warrant further attention. Third, in the Level 2 analysis, predictors of the individual slopes and intercepts are analysed for their explanatory power.

Results

Results for all four research questions are provided in Table 3. Results for each research question are discussed below.

Research Question #1: Are there significant differences in growth rates and predicted reading abilities at age eight as measured by scores on the TERA between children with disabilities and without disabilities?

Table 3. HLM coefficients (and *p*-values) of the influence of disability status, gender and preschool block scale score on growth rates of TERA reading scores and TEMA math scores ($n = 51$).

	TERA score (age 8)	TERA growth rate	TEMA score (age 8)	TEMA growth rate
Intercept (β_0)	33.109 (.000)	.511 (.000)	45.534 (.000)	.725 (.000)
Disability status (β_1)	−11.263 (.002)	−.159 (.029)	−13.755 (.003)	−.118 (.180)
Gender (β_2)	−2.249 (.480)	−.031 (.639)	−5.183 (.216)	−.094 (.273)
Preschool block score (β_3)	1.001 (.011)	.024 (.004)	.531 (.216)	.011 (.184)

Research Question #2: Are there significant differences in growth rates and predicted maths abilities as measured by scores on the TEMA between children with disabilities and without disabilities?

The findings reported in Table 3 show that there were statistically significant differences between predicted TERA scores of children with and without disabilities at age eight ($\beta_1 = -11.263$, $p < .002$). This means that children with disabilities are predicted to score 11.26 points lower than children without disabilities at age eight. More specifically, children without disabilities are predicted to have a score of 33.11 on the TERA ($\beta_0 = 33.109$) and children with disabilities, 21.88.[3]

Similarly, TERA growth rates through ages five to eight also differed significantly between children with disabilities and children without disabilities ($\beta_1 = -.159$, $p < .029$). This means that children without disabilities are predicted to grow at a rate of about one half point per month on the TERA ($\beta_0 = .511$) compared to children with disabilities, whose growth rate is estimated to be about one third of a point in TERA ($\beta_0 – \beta_1 = .352$).

Findings were different for maths scores. That is, TEMA predicted scores at age eight were influenced by disability status ($\beta_1 = -13.755$, $p < .003$). Thus, children without disabilities are predicted to have a score of 45.53 on the TEMA ($\beta_0 = 45.535$) and children with disabilities, 31.78. However, disability status had no significant influence on growth rates in maths ($\beta_1 = -.118$, $p < .180$).

Research Question #3: Is there a significant effect of highest score in block constructions on growth rates of reading abilities and predicted reading abilities at age eight as measured by TERA scores?

Research Question #4: Is there a significant effect of highest score in block constructions on growth rates of maths abilities and predicted maths abilities at age eight as measured by TEMA scores?

Findings reported in Table 3 show that there was a statistically significant effect of children's block construction score on predicted TERA score at age eight ($\beta_3 = 1.001$, $p < .011$). This means, for example, that a child with a block scale score five points higher than the mean in preschool would be predicted to score 5.01 (5 x 1.001) points higher on the TERA at age eight.

The block score in preschool also predicted the growth rate in TERA scores at ages five through eight (β_3 = .024, p < .004). Thus, using the same example, a child with a five-point advantage in preschool block score is predicted to have a .12 advantage in TERA growth rate per month.

There was no significant effect of block construction scale score on predicted TEMA score at age eight or growth rate in TEMA scores.

Discussion

The purpose of this study was to explore the predictive relationship between the level of symbolic representation in preschoolers' block constructions and reading and mathematics abilities and rate of growth from ages five to eight for children with and without disabilities. An additional purpose of the study was to determine if rates of growth and academic achievement in early elementary years differed between children with and without disabilities. Fifty-one children participated, 22 of whom had identified disabilities.

Growth curve analysis revealed that children with disabilities had lower predicted reading and maths scores at age eight and progressed at a slower rate in reading abilities in the early elementary years. These findings are not unexpected and parallel those of other research related to the learning and development of children with disabilities. That is, children with disabilities generally tend to not progress as quickly in academic learning as their peers without disabilities (e.g. Sabornie, Cullinan, & Osborne, 2005; Turner & Alborz, 2003).

No predictive relationship between representational level of block constructions and maths abilities was found. This finding is similar to that of two other studies (Stannard et al., 2001; Wolfgang et al., 2001) in which no relationship was found between preschool construction play behaviours (including block play) and mathematical achievement in elementary grades. The authors of these studies, however, did find a positive relationship between preschool construction play and middle and high school maths achievement. It is possible that the influence of block play is not evident until children move into formal operations (Piaget, 1977) and underlying cognitive structures that develop through block play do not influence maths abilities until the maths curriculum requires higher abstract mathematics such as geometry, trigonometry and calculus. It is also possible that preschool block play did not affect the numbering skills, numeral literacy, number facts and calculation skills assessed by the TEMA.

Although a relationship between preschool block play and elementary maths abilities was not found, growth curve analysis documented that preschoolers who had higher scores in block construction had higher predicted TERA scores at age eight, as well as a faster rate of growth in TERA scores in early elementary grades. That is, children who had higher levels of representation in their block constructions had higher reading abilities and a faster rate of growth in reading abilities in the early elementary years. This predictive relationship held true for children with and without disabilities.

The relationship between block play and reading abilities is most likely explained by the enriched block experiences provided to the children in this study. Children were provided block experiences that optimised representational learning, language development and other emergent literacy skills. The emphasis on these developmental areas of learning within the context of block play may have contributed to the relationship with later literacy skills. The best early predictors of eventual competency in later literacy appear to be speech and language abilities (particularly vocabulary), phonological awareness and familiarity with the alphabetic principle (Strickland & Shanahan, 2004; Whitehurst & Lonigan, 2001). In block play, the children in this study had experience with literacy materials; activities focused on increasing vocabulary and structure that supported oral language development.

Books were available to children in the block centre and were often used to introduce the block play. The introduction of the block play also included an emphasis on vocabulary associated with block construction. Further, during block play, the teacher continued to scaffold the children's individual experience by enhancing and extending the children's language, increasing socialisation opportunities through support of communication within peer interactions and modelling appropriate communication during individual conversations. The consistency of the same adult in the block play area allowed him to capitalise on children's prior knowledge and experience when scaffolding the block play.

In addition, after completing their block construction, children were allowed to choose micro-dramatic play props and engage in socio-dramatic play with peers, providing opportunities to increase language and representational skills. The 90-minute period allowed the children time to build complex block structures, engage in elaborate socio-dramatic play, and process and understand their experience. Additional time to play with blocks was provided at other times throughout the day reinforcing learning.

Vygotsky (1978) theorised that representational play experiences are an important step towards using and processing written symbols. Representational play helps children act independently from what they see. In representational play, therefore, thought is separated from objects, and action comes from ideas rather than from things. This change in the way a child thinks does not happen all at once, but play provides a transition from situational constraints that dominate actions and thoughts in the early childhood years to the symbolic thinking required to understand written symbols.

There are several limitations that should be noted in this study. First, the small number of children included in the study and the fact that all children attended the same preschool makes generalisation of results difficult. Second, the type of disability was not controlled for in the analysis. There may well be variance within this group that could be further explained through classifying the type or severity of their disabilities. In addition, the analysis established a statistical relationship between block play and academic abilities, not a causal relationship.

Conclusion

The use of blocks varies greatly in today's early childhood programmes. In some programmes, time spent playing with blocks is not viewed as a constructive use of children's time in comparison to readiness workbooks, computer tasks and teacher-directed interventions. However, the findings of this study provide support for play activities that are physically and socially organised to provide young children with and without disabilities the experiences that build the foundation for later learning. The inclusion of vocabulary development, representational construction, socio-dramtic play and literacy materials within block play provides experiences for young children that may help them build the cognitive structures that support later literacy learning. Additional longitudinal research, however, is needed to establish causal relationships between early play experiences and later learning and to compare the efficacy of play-based approaches to other methods.

Notes

1. The contents of this report were developed under an Early Childhood Demonstration U.S. Department of Education grant (HO24B40064). However, the contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government.
2. Please note that testing began before the *TERA-3* (Reid, Hresko, & Hammill, 2001) and the *TEMA-3* (Ginsburg & Baroody, 2003) were developed. For purposes of consistency, the *TERA-2* and the *TEMA-2* were used throughout the study.
3. We also specified a model that included an interaction between disability status and last block score. This model provides an estimate as to whether the effect of block score on outcomes differs for children with disabilities and children without disabilities. The effect of the interaction on reading and maths scores and growth rates was not significant. Thus, we estimated the more parsimonious model.

Notes on contributors

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