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Playing with Building Block: a Way to Improve Numerical Intelligence and Nonverbal Reasoning

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Abstract

Learning through playing represents a fundamental aspect of children's intellectual development. Many studies stated the significant relationship among building block play, visual spatial ability, mental imagery, mathematical and geometric skills (Caldera, 1999; Wolfgang, 2003; Pirrone & Di Nuovo, 2014).
The main aim of this longitudinal study was to investigate the strengthening of some cognitive abilities as discrimination, perception, attention that represent the basis for formal reasoning and learning mathematics, using LEGO blocks. The tests used in the two phases, pre and post research, were the Colored Progressive Matrices (CPM) Test (Raven, 1947) and the Battery for the Assessment of Numerical Intelligence (BIN) (Molin, 2007). A group of 19 children aged 5, played 3 times a week for 50 minutes, for 7 months. Teacher and Researcher asked the pupils to use LEGO bricks to carry out classification based on various criteria (colors, shapes, size, etc.), to compare different numbers associating them with the corresponding quantity; to build something imagined and discussed before. At the end of the session, the children made drawing and told us what they had done, spending the remaining time playing with LEGO freely. The results obtained using Student's test, show significant increases in both Raven's CPM and in all BIN's area ($p<.001$). These results may offer suggestions for educational processes in the early and middle stages of development aimed at enhancing performance in these areas and will therefore be useful for improving academic learning.

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Keywords: building block play; nonverbal reasoning; mathematics, numerical intelligence

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1. Introduction

Learning through playing represents a fundamental aspect of children's social, emotional and intellectual development. A certain kind of play, like Building Block Play (BBP) can foster creativity and deeper learning. While using hands-on blocks, children explore their imagination by rebuilding and realizing their ideas. At the same time they become, unconsciously, mentally active, and learn to interpret and process sensory information. Piaget (1945) and Reifel (1984) stated that children can learn mathematical and geometric concepts (e.g., shape and size), create topological knowledge, and learn to match and group through building-block play. Even before they can label or describe blocks, children have internalized the blocks' physical attributes and established an important relationship between the objects. In block play, children classify, measure, order, count, use fractions, become aware of depth, width, length symmetry, and space (Hirsch,1996), understand equivalencies and part-to-whole relationships, and increase and promote problem-solving skills and logical thinking. Building-block play furnishes opportunities to learn and practice visual perception along with gross and fine motor skills when children manipulate and assemble pieces, (Pirrone et al., 2015). According to Verdine (2014) playing with blocks may be crucial in helping Pre-schoolers to develop "spatial thinking", envisioning where blocks go in relationship to each other as they build. Deciding whether a block goes over or under another block, or whether it is aligned or perpendicular to it, are the kinds of analysis skills that support later learning in science, technology, engineering, and math (STEM). Structured block play has been hypothesized to develop skills in estimation, measurement, patterning, part–whole relations, visualization, symmetry, transformation, and balance (Casey & Bobb, 2003). When children play with building blocks, they are encouraged to reason continuously, contributing to the development of children's math and can foster children's development as well as contribute to more advanced building (Ramani, et al. 2014). Recent studies that aimed to analyse the relationship between construction play and cognitive abilities have mostly focused on spatial ability and visual spatial ability (Brosnan, 1998; Caldera, 1999; Nath & Szucs, 2014;), more so than on mathematical and geometric skills and mental imagery (Caldera, 1999; Wolfgang, 2003; Pirrone & Di Nuovo, 2014, Pirrone et al.,2015). In summary, the scientific literature reports a positive relation between children's constructive play activities and spatial ability, but, there is a dearth of longitudinal studies suggesting stronger relationships in terms of causality among BBP, numerical intelligence and nonverbal reasoning.

2. Method

The main aim of this longitudinal study was to investigate the influence of LEGO TM block play on preschool children's cognitive abilities related to discrimination, perception, and attention, that represent the basis for formal reasoning and learning mathematics. We tested the hypothesis that children who regularly play with LEGO blocks will show a statistically significant increases in the logical-mathematical thought and nonverbal reasoning.

2. 1 Participants

Participants were 19 preschool children, 11 males and 8 females, assessed at two time-points: an initial assessment between 59 and at 69 months of age (M= 63.21; SD 3,04) and 7 months late, between 65 and at 75 months of age (M= 69.21; SD 3,04). Participants were from varied socio-economic (SES) backgrounds.

2.2 Setting

Play sessions were structured twice a week as free play, once a week as structured play. Each session was 50 minutes and the sessions continued for 7 months during the regular school year. There were also free-play sessions. The sessions were divided into individual and small-group play. In free play children choose whether to play alone or with a partner, and they chose the specific template for the object they were to build. They also chose the number of blocks to be used. During the structured session play, the teacher and researcher asked the pupils to use LEGO blocks to carry out classification tasks based on various criteria (colors, shapes, size, etc.), to compare numbers associating them with corresponding quantities; to compare sets with different numerosity (matching each element of the set A with the set B); and order items of different sizes in ascending and descending order. At the end of the session the children drew pictures of what they built. To stimulate their analysis skills further, the children were asked to place various objects and themselves in a specific portion of their creation (right, left, top, bottom, center). To enhance their ability to follow the rules of composition, the children were asked to build such things as a house, a car, a farm, etc., by following a specific model represented by pictures. To develop and increase their skills to create connections between personal experiences and conceptualization of those experiences, the children were presented with a general topic, to "frame" a creative design (e.g. water, fire, sky, etc.). The children had to verbalize all that the words that stimulated their imagination. Subsequently, each child represented the chosen word with LEGO blocks and then through drawing. The free session play was aimed to stimulate mental imagery. Prior to building the teacher engaged the students in a brainstorming strategy (e.g. what I want to build?), and after building by asking them to explain what they had created. had been building using LEGO blocks.

2.3 Measures

2.3.1 The Colored Progressive Matrices (CPM) Test (Raven, 1947)

This test is a non-verbal multiple-choice test that evaluates general cognitive abilities: logical reasoning, classification and comparison of structures, deductive ability, understanding analogies and sequential processes, and reversible thinking. A configuration with a missing piece is presented to the student, who is asked to complete it by indicating which of the eight alternatives shown at the bottom of the page completes the matrix. It is administered individually, and the time limit is 20 minutes. The total score is the number of correct answers. This raw total score can be converted to its corresponding percentile for Italian children of the same age (Belacchi, Scalisi, Cannoni & Cornoldi, 2008).

2.3.2 The Battery for the Assessment of Intelligence Numerical -Bin 4-6 - (Molin et al. 2007)

This battery helps identify the early mathematical development of children as well as identify children who are at risk in the area numerical intelligence for children aged 4 to 6. The battery consists of 11 trials investigating 4 specific areas: (1) Lexical Area (e.g. writing numbers, correspondation name-number); (2) Semantic Area (e.g., comparison between quantity and numbers); (3) Counting Area (e.g. enumeration forward and backward, seriation Arabic numbers;) and (4) Area of Pre-Syntax (e.g. matching between Arabic code –quantity, order of size). The battery provides a total score for the overall assessment and specific scores for each area expressed as a continuum of performance: a) criteria completely achieved, b) sufficient performance, c) more practice necessary c) request for immediate intervention.

3. Results

A preliminary analysis compared the performances by gender, which did not significantly affect the tests outcome. Therefore, further analyses were conducted without gender distinction.

Table 1. Chi-square pre and post-test: distribution of the sample in the percentiles' CPM

CPM Percentile	**Pre-Test** **N. of subjects** ***f***	**Post-Test** **N. of subjects** ***f***
1-5	0	0
6-25	1	0
26-50	3	2
51-75	10	5
76-90	4	4
91-99	1	8
Total	19	19

Tab. 1 shows the differences between the two phases, pre- and post-test. At the post-test just two students remained in the lower levels of performance. Those students who performed between the 51th and 75th percentile were reduced to 5, whereas 8 students moved to the upper levels of performance between the 91th and 99th percentile ($\chi2$ (12)= 19,135; p<.05). This means that the 42% of the sample reached the highest levels of achievement.

Table 2. Chi-square pre and post-test: distribution of the sample in the 4 BIN's area

BIN Area	**Pre-Test** **N. of subjects** ***f***	**Post-Test** **N. of subjects** ***f***
A) criteria completely achieved	3	12
B) sufficient performance	11	5
C) attention request	4	2
D) request for immediate intervention	1	0
Total	19	19

The results of the post-test, suggest a statistically significant shift of the majority of the students toward superior areas. Twelve subjects achieved the highest level on the pre-test compared to 3 on the pre-test. Children in the sufficient performance area increased to 11 on the post-test ($\chi2$ (8)= 23,013; p<.005), from 5 on the pre-test and the number of students in need of immediate attention was reduced to 0.

Table 3. Paired *t* test for differences between pre- and post-tests (CPM and BIN).

Variables	**M**	**SD**	**paired *t***	**p**
Pre-CPM	16,11	3,61		
Post- CPM	21,63	6,48	-4,76	,001
Pre-tot-area-lexical	17,47	5,61		
Post-tot -area- lexical	22,11	1,82	-4,80	,001
Pre-tot-area-semantic	17,84	2,65		
Post-tot-area-semantic	18,84	2,43	-1,71	,103
Pre-tot-counting	27,26	9,62		
Post-tot-counting	35,74	8,06	-4,66	,001
Pre-tot-area-pre syntax	15,11	4,97		
Post-tot-area- pre syntax	19,47	1,98	-4,82	,001
Pre-tot-BIN	77,58	19,28		
Post-tot-BIN	96,26	11,63	-6,28	,001

The results of the paired t-test suggest statistically significant increases from the pre- test to post-test phases in both Raven's CPM and in almost all BIN's areas (p<.001), excluding the results from the semantic abilities (P> 0.10). Pearson's correlation, at the pre-test phase, were not statistically significant among age, CPM (p=.300; p>.21), and BIN (p=.359; p>.13), nor beetween the CPM and BIN tests (p=.447; p>.055). At the post-test phase thee were not statistically significant correlations among age, CPM (p=.033; p>.896), and BIN (p=.205; p>.40). However, there was a positive, statistically significant correlation between the total scores of Raven and the total scores of BIN (p=.565; p<.01)

4. Conclusion

Findings from this study suggest that BBP has a statistically significant effect on students' performance in mathematics and nonverbal reasoning, confirming our hypothesis about the possibility to increase the numerical intelligence and nonverbal reasoning through active play with LEGO blocks. The lack of a gender influence in this age range contradicts the old stereotype of gender in which males were believed to perform better than females in mathematics. The children's significant shift toward higher achievement on the CPM test, suggests that playing with LEGO blocks improves mathematics skills such as logical thinking, reasoning, attention, visual spatial ability, understanding three-dimensionality, and perceptual and discriminative skills and thinking (Pirrone 2012, Pirrone & Commodari, 2013).

The increases of children's performance toward higher areas on the BIN battery suggests to us that the mathematical prerequisites are not only innate in this age range but can be enhanced through appropriate guided play activities (Ramani et al., 2014). Even if BBP is already frequently a free play activity in early childhood classrooms, incorporating guided play activities may be an enjoyable and motivating way for children to purposefully learn, practice, and develop important skills (Hirsh-Pasek et al., 2009). As Kersh et al. (2008) stated, guided play activities with peers could increase the problem-solving skills children use when building in more unstructured block play. This

conclusion is supported by the statistically significant differences in all BIN areas and the CPM on the pre and post-tests, strengthening the belief that BBP improves children's mathematical and general cognitive skills.
An interesting finding was the lack of age influence on the pre- and post-test results. Given the speed at which cognitive development proceeds in the age range of our sample, we expected that the age could affect the results, at least, in the post test phase. Although the pre-test results demonstrated no statistically significant correlations between BIN and CPM, the post-test results suggested a strong, statistically significant, positive relationship between BIN and CPM. Once again, this finding leads us to think that improvements achieved at the end of the experimentation are due to the guided play activities with LEGO blocks. The results of the study may have important implications for early childhood classrooms and avenues for future teacher preparation programs. One possible implication is the importance of teaching pre-service teachers how to use BBP to promote an intuitive, implicit conceptual foundation for mathematics, and, the importance and effectiveness of learning through free and structured play. Further research could strengthen these results by investigating them in other age ranges and with larger samples, and also through the use of control groups. Moreover, future research could include the use of affective and emotional variables along with cognitive variables.

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