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Investigating the Effectiveness of More to Math Educational Lego on Math Progress, Spatial Understanding, Working Memory, and Processing Speed Among Female First Grade of Elementary School

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ABSTRACT

The current study examined the effectiveness of the educational Lego “More Math” on the mathematical progress, spatial understanding, working memory, and processing speed of students in female first grade of elementary school. female first-grade students. The research employed a quasi-experimental design incorporating a pre-test and post-test framework, with the inclusion of a control group. The population of this study consisted of female first-grade students studying in the schools of Tehran District 14 in the academic year 2022-2023. Among the available schools in District 14, Mihrab Girl’s Elementary School was selected as the sample. Then, 30 students were selected by convenience sampling and randomly assigned to the experimental (15 students) and control (15 students) groups. The data were collected by the Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V), which consisted of ten sub-tests comprising five sub-scales for fluency, language comprehension, visual-spatial reasoning, processing speed, and working memory, and the teacher-made math test. The Lego More to Math educational protocol consisted of weekly training sessions over the course of 15 weeks, with each session lasting for 60 minutes. The data were analyzed using univariate and multivariate analyses of covariance by SPSS26.The analysis revealed significant differences between groups for spatial perception ($F = 1.48$, $p = 0.00$, $\eta^2 = 0.36$), working memory ($F = 12.13$, $p = 0.00$, $\eta^2 = 0.32$), processing speed ($F = 18.16$, $p = 0.00$, $\eta^2 = 0.42$), and math progress ($F = 5.78$, p = 0f00, $\eta^2 = 0.29$, test power = 0.9), with non-significant pre-test results ($p = 0.88$) and significant group differences ($F = 11.36$, $p = 0.00$). The study demonstrated that the Lego "More to Math" educational program significantly enhanced first graders' mathematical progress, spatial understanding, working memory, and processing speed. These findings suggested that incorporating structured, play-based learning tools like Lego into early education effectively boosted cognitive and mathematical skills in young students.

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Introduction

Mathematics is a fundamental discipline that underpins much of modern science, technology, and everyday decision-making. It is the study of structure, organization, and quantity, and its importance in the educational system cannot be overstated (Gyamfi, 2022). Mathematical competence is not only essential for academic success but also for the development of logical thinking and problem-solving abilities that are critical throughout life (Sepehrianazar et al., 2023). Early exposure to mathematics, whether at home or in early educational settings, has been shown to lay a critical foundation for later learning, influencing a child's future academic trajectory (Sarama & Clements, 2015). Despite its importance, mathematics remains a challenging subject for a significant portion of the population, with an estimated 15-20% of individuals experiencing some form of mathematical learning difficulty (Siagian et al., 2019). These difficulties are not just isolated to mathematical concepts themselves but are often intertwined with broader cognitive processes such as working memory, processing speed, and spatial reasoning (Atit et al., 2020; Fariso-van den Bos et al., 2013; Liu et al., 202; Passolunghi & Lanfranchi, 2012;).

Mathematical academic achievement in early education is foundational for future academic success and cognitive development. Traditional teaching methods often struggle to engage young students, particularly in subjects like mathematics that require abstract thinking and problem-solving skills (Abdulwahed et al., 2012; Kaiser et al., 2011). The Lego "More to Math" program, designed to integrate play with learning, offers an alternative approach that may not only make math more accessible but also enhance overall academic achievement (Amalric & Dehaene, 2018). By encouraging hands-on activities and collaborative learning, this program could help students develop a deeper understanding of mathematical concepts, thereby improving their academic performance in mathematics.

Beyond improving direct mathematical skills, enhancing mathematical progress is closely linked with the development of other cognitive abilities, particularly spatial understanding. Spatial skills are fundamental to understanding and solving mathematical problems because they allow students to visualize relationships and manipulate abstract concepts in their minds. This link between mathematical progress and spatial understanding highlights the importance of fostering both skills concurrently in educational programs. Spatial understanding refers to the ability to mentally manipulate, organize, and reason about objects in space. It plays a critical role in a variety of everyday tasks and is especially important in fields that require an understanding of geometry, measurement, and the physical relationships between objects. Spatial skills have long been recognized as a key factor in mathematical performance, with a robust body of research demonstrating strong and consistent correlations between spatial and mathematical abilities (Hawes & Ansari, 2020; Lourenco et al., 2018; Xie et al., 2020). In the context of early education, spatial skills enable students to comprehend and solve problems that involve geometric reasoning, pattern recognition, and the visualization of numerical relationships (Cimadevilla & Piccardi, 2020; Uttal et al., 2013). These skills are not only essential for success in specific mathematical tasks but also serve as a foundation for more complex cognitive processes that students will encounter as they advance in their education. Enhancing spatial understanding at an early age can thus have long-lasting effects on a student's overall academic and cognitive development.

Another variable related to spatial understanding is working memory. Spatial understanding and working memory are intricately linked cognitive functions that both play crucial roles in mathematical learning (Fuster, 2022; Lee-Cultura & Giannakos, 2020; Takeuchi et al., 2010). Spatial understanding involves the ability to visualize, manipulate, and reason about objects and their relationships in space (Gecü-Parmaksız, 2017; Uhlenberg & Geiken, 2021). This cognitive skill is fundamental for solving geometric and spatial problems, where students must mentally organize and transform spatial information. On the other hand, working memory is responsible for the temporary storage and simultaneous processing of information (Farazandeh et al., 2023). Effective spatial reasoning relies on working memory to retain and manage spatial information, enabling students to manipulate geometric shapes and solve spatial configurations effectively.

When students engage in tasks that require spatial understanding, such as solving problems involving geometric shapes or spatial arrangements, they must utilize their working memory to hold and process the relevant spatial information (Gecü-Parmaksız, 2017; Liben, 2013). For instance, understanding how different shapes fit together or how to navigate a spatial problem involves maintaining several pieces of information in mind simultaneously. This interaction highlights how the development of spatial understanding can significantly impact working memory. As students enhance their spatial skills through activities like those provided by the Lego "More to Math" program, they concurrently improve their working memory capabilities, as both cognitive functions are engaged and developed together.

Working memory is particularly vital in the context of mathematics, where it supports various cognitive processes essential for problem-solving. It is involved in tasks such as counting, retrieving arithmetic facts, and performing calculations (Liang et al., 2022; Loazia & Camos, 2018). Low working memory capacity has been linked to difficulties in automating basic counting sequences and acquiring number knowledge (Destefano & Lefevre, 2004; Furst & Hitch, 2000). Research has consistently shown that working memory is crucial for accurate calculation, addition, subtraction, and mental arithmetic (Qi et al., 2022; Silverman & Ashkenazi, 2022). By improving spatial understanding through targeted interventions, students can potentially enhance their working memory, leading to more effective problem-solving and mathematical reasoning. This integrated approach underscores the importance of using educational tools that address both spatial and memory skills to foster comprehensive cognitive development.

While working memory is essential for temporarily storing and processing information, another crucial cognitive function that impacts mathematical performance is processing speed. Processing speed refers to the time required to comprehend, process, and respond to information (Swanson & Harris, 2013). This cognitive ability significantly predicts children's mathematical performance, as it affects how quickly and efficiently they can execute mathematical tasks and solve problems (Berg, 2008). The relationship between working memory and processing speed is nuanced yet important. Working memory involves holding and manipulating information, whereas processing speed pertains to the rate at which information is processed and acted upon. Despite the critical role of working memory, research indicates that processing speed also plays a significant role in mathematical abilities, independently of working memory capacity (Fuchs et al., 2006; 2012). For example, processing speed influences how quickly students can complete calculations, retrieve arithmetic facts, and perform multi-step problem-solving tasks. Processing speed is particularly crucial during elementary school, a period when children are acquiring fundamental reading and math skills and developing the speed and automaticity required for effective learning (Flanagan & Mascolo, 2005). Faster processing speed allows students to engage more fluidly with mathematical tasks and enhances their ability to keep pace with the demands of the curriculum (Fernández Cueli et al., 2020; Xie et al., 2020). As such, improving processing speed can have a direct impact on overall mathematical achievement, complementing the benefits gained from enhanced working memory and spatial understanding (Fernández Cueli et al., 2020). This transition from working memory to processing speed highlights the interconnected nature of cognitive functions in mathematical learning. As students work on enhancing their working memory through various educational interventions, it is also essential to address processing speed to support their overall mathematical development. By integrating strategies that target both working memory and processing speed, educational programs can more effectively improve students' mathematical performance and cognitive efficiency.

The information presented indicates that academic performance, especially in mathematics, is significantly influenced by both cognitive abilities and environmental factors (Peng & Kievit, 2020; Tikhomirova et al., 2020). Cognitive skills and educational settings are integral to academic development (Ketel, 1987). Educational games, such as Lego, function as stimulating elements within the learning environment and have the potential to enhance both teaching and learning outcomes (Castronovo, 2022; Clark et al., 2016). Empirical research further supports the efficacy of games as valuable educational tools, highlighting their role in facilitating engagement and improving academic achievement (Boyle et al., 2016).

Lego bricks, first introduced in 1958, have since transformed into an extensive range of thematic kits and educational play solutions (Mortensen, 2012). These bricks are utilized in what is described as cooperative play therapy, where children collaboratively construct various models, promoting both teamwork and creative problem-solving (LeGoff et al., 2014). A review by Xia and Zhong (2018), which analyzed 22 journal articles on robotics education, showed that despite the widespread integration of Lego into educational environments, its impact on learning outcomes, particularly in the domain of mathematics, remains an area of active research and debate. As the significance of mathematical proficiency grows across various fields—including science, technology, and engineering—the limitations of traditional passive learning methods have become increasingly evident. These conventional approaches often fail to fully engage students or address the multifaceted cognitive processes involved in mathematical learning (Hartt et al., 2020; McDougal et al., 2024; PsyPost, 2024). This study sought to bridge the gap in understanding the effectiveness of the Lego-based educational program "More to Math" in enhancing key cognitive and academic skills among first-grade students in Iran. Specifically, the research explored the following questions:

Does participation in the "More to Math" program enhance students' understanding and performance in mathematics, including their ability to grasp foundational concepts and solve mathematical problems?

How does the program impact students' ability to visualize and manipulate geometric shapes and spatial relationships, which are essential for solving complex mathematical problems?

Can engagement with Lego-based activities support the development of working memory, which is crucial for retaining and processing information necessary for mathematical reasoning?

Does the program contribute to faster processing of mathematical tasks and problems, thereby enhancing students' ability to execute and complete mathematical operations efficiently?

Method

Design

The current study aimed to evaluate the effectiveness of the Lego-based "More to Math" program in enhancing mathematical learning and cognitive skills among first-grade students. This quasi-experimental study employed a pre-test and post-test design, with participants randomly assigned to either an experimental group or a control group, which did not receive the intervention until after the study's conclusion.

Participants

The sample comprised female first-grade students from District 14 of Tehran during the 2022-2023 academic year. Mihrab Girl's Elementary School was selected as the research site, with a total of 30 students participating in the study. A cluster sampling method was utilized, where entire classrooms or groups within the selected district were chosen as clusters to represent the broader population. This approach ensured that the sample accurately reflected the target demographic of first-grade female students in this district.

Participants in the experimental group received 15 weekly sessions of the Lego-based program, designed to integrate mathematical concepts with hands-on learning experiences, while those in the control group remained on a waitlist, receiving no intervention during the study period. The inclusion criteria required students to be aged 7 to 8 years, female, not on any medication, physically capable of participating in the activities, and having informed consent from both the students and their parents. Exclusion criteria included students unwilling to continue participation, those who missed more than two sessions, and those receiving concurrent psychiatric or psychological interventions.

The study adhered to rigorous ethical standards, including obtaining informed consent from guardians and ensuring participant confidentiality throughout the research process. The content of the "More to Math" program is detailed in Table 1, outlining the specific educational modules and activities implemented during the intervention.

Table 1

Summary of the Lego More to Math Educational Protocol

No.	Session title	Description
1	Sudoku	To introduce the members to each other and the instructor and provide explanations about training sessions, reasoning, and problem-solving by completing Sudoku
2	Park pavement	To continue the checkerboard patterns and find the repeating shape
3	Butterflies 1	To get familiar with the column chart, completion of the symmetrical figure
4	Butterflies 2	To understand and recognize the symmetry
5	Snakes	To write the sums of a number and draw a bar graph
6	Chickens 1	To solve the problem of addition and subtraction and different combinations of No. ten
7	Flowers 1	To use groups of one and ten
8	Chickens 3	To solve the problem of addition and subtraction, preparing to understand the concept of division and different combinations of ten
9	Flowers 2	To understand binary and one categories and to solve the addition and subtraction problems
10	Train 1	To practice counting, bar charts, and comparing numbers
11	Biscuit 2	Count three, three
12	Flowers 3	To understand the categories of tens and ones and to solve the problem of adding and subtracting decimals
13	Strawberry 2	To understand and solve the addition and subtraction problem
14	Store	To understand the place value table and one and two categories
15	Train 3	To find a pattern and design a repeating pattern

Instruments

Wechsler Intelligence Scale for Children – Fifth Edition: The ten main sub-tests to measure the main cognitive abilities and intelligence are: 1. Design of cubes, 2. Similarities, 3. Matrix reasoning, 4. Digit span, 5. Coding, 6. Vocabulary, 7. Recognition of weights, 8. Visual puzzles, 9. Image space, and 10. Symbolization. The indicators obtained from implementing ten main subtests are Fluid Reasoning, Verbal Comprehension, Visual-Spatial, Processing Speed, and Working Memory.

Wechsler's working memory test :The minimum score of the examinee in this test is 0, the maximum score is 20, and the cut-off point in this test is 10. In a research, test-retest coefficients for small tests and combinations were obtained from .28 to .98, which is satisfactory. Also, the measurement error in this research was calculated as the most reliable index was the attention/concentration index and then the verbal memory index (Orangi et al., 2013).

Wechsler'. p. ocessing speed test: Wechsler (2003) used the test-retest method to determine the reliability coefficient of the subscales and IQ scores, reporting a reliability coefficient of .82 for working memory and .97 for total IQ. Sadeghi et al. (2013) found a significant correlation between the fourth edition of the Kessler Scale of Children's Intelligence, the revised scale of children's intelligence, and Kessler and Raven's Progressive Matrices. All subscales had adequate to excellent bisecting coefficients, and the test-retest reliability coefficients were sufficient to excellent, except for the visual concepts subscale.

Spatial understanding: Wechsler (2003) has used the retest method to check the reliability coefficient of the subscales and IQ scores using the split-half method, and in the case of the sub-scales of encoding, symbolization, because they are a speed test. The reliability coefficient of the working memory test has been reported as 0.82, and the reliability coefficient of the total IQ has been reported as 0.97. The classification of subtests is reported from 0.43 to 0.94.

Academic progress: The academic progress in mathematics was assessed by a teacher-made test for the first and the second midterms administered before and after the implementation of the educational program in the same way for both control and experimental groups. According to Pintridge and DeGroot (1990), teacher-made tests are more similar to regular school tests and are more suitable as research tools than standard tests.

Data Analysis

All data were analyzed using SPSS version 24. Analysis was conducted using Analysis of Covariance (ANCOVA) and Multivariate Analysis of Covariance (MANCOVA).

Results

Descriptive statistics

Table 2 presents the demographic characteristics of the participants in both the intervention and control groups.

Procedure

To gather information in a targeted manner, relevant keywords related to personal branding were searched in the Google Scholar, Research Gate, ScienceDirect, ERIC, Springer, ProQuest, and Academia.edu databases, limiting the publication date range from 2000 to 2023. The initial search yielded 7,641 sources. Next, keywords related to digital storytelling were added, and the number of sources found was reduced to 1,495. Subsequently, keywords related to the research community were added, and 284 sources were obtained. Then, duplicate sources and sources with titles unrelated to the research topic were removed, leaving 102 sources. Upon reviewing the abstracts of the sources, documents whose abstracts were not relevant to the current research were excluded, and a total of 23 sources were selected for study. After reviewing the full content of the sources and removing those with inappropriate content, 13 sources were selected as the final sources for content analysis. Based on the study and analysis of the obtained sources, interview questions were designed and conducted with experts in business management, technology management and entrepreneurship, tourism management, measurement and evaluation, and information and knowledge science who had academic or practical experience in personal branding. The interviewees were selected in a targeted manner, and their number was determined based on theoretical saturation. The interviews were conducted in a semi-structured manner, using a flexible framework adapted to the information provided by the interviewees. After thematic analysis of the interviews and combining the obtained data with the results of the content analysis, the final categories for shaping the model were determined. Figure 2 shows the steps of the research data collection.

Table 2

Descriptive Statistics of Demographic Characteristics of Participants

Demographic variable		Groups		Test results
		Intervention N (%)	control N (%)	
aa ther’s education level	High school and diploma	4(26.7)	5(33.3)	$\chi^2(2)= 0.8$
	Bachelor’s degree	7(46.6)	8(53.4)	P= 0.06
	Masters degree and higher	4(26.7)	2(13.3)	
Mother’s education level	high school and diploma	2(13.3)	3(20)	$\chi^2(2)= 0.3$
	Bachelor’s degree	8(53.4)	8(53.4)	P= 0.8
	Masters degree and higher	5(33.3)	4(26.6)	
aa ther’s job *	Self-employed	11(73.3)	13(86.7)	P= 0.6
	Employee	4(26.7)	2(13.3)	
Mother’s job	Housekeeper	8(53.4)	9(60)	$\chi^2(2)= 0.86$
	Employee	3(20)	4(26.7)	P= 0.64
	freelancer	4(26.7)	2(13.3)	
Income status	Low	2(13.3)	3(20)	$\chi^2(2)= 0.91$
	Medium	9(60)	10(66.7)	P= 0.63
	high	4(26.7)	2(13.3)	

The distribution of the father’s education level shows that in the intervention group, 26.7% had high school and diploma-level education, 46.6% held a bachelor’s degree, and 26.7% had a master’s degree or higher, while in the control group, 33.3% had a high school diploma, 53.4% held a bachelor’s degree, and 13.3% had a master’s degree or higher. For the mother’s education level, the distribution was similar across both groups, with 13.3% to 20% having a high school diploma, 53.4% holding a bachelor’s degree, and 26.6% to 33.3% having a master’s degree or higher. Regarding employment, 73.3% of fathers in the intervention group were self-employed compared to 86.7% in the control group. Mothers were primarily housewives, with 53.4% in the intervention group and 60% in the control group. Income status showed that most participants reported a medium income level, with 60% in the intervention group and 66.7% in the control group, while a smaller percentage reported low or high income. The chi-square tests indicated no statistically significant differences between the groups across thes demographic variables, suggesting that the groups were comparable.

Table 3

Descriptive Statistics of Math Progress (Mathematics Grade) and Components of Spatial Understanding, Working Memory, and Processing Speed by Groups (n= 30)

Variable	Stage	Math educational Lego		Control	
		Mean	SD	Mean	SD
Math progress	Pre-Test	15.93	2.18	15.26	1.69
	Post-Test	17.4	1.91	15.33	1.29
Spatial perception	Pre-Test	15.66	2.82	14.2	4.24
	Post-Test	19.73	2.89	14.8	4.09
Working memory	Pre-Test	10.26	2.96	9.73	2.98
	Post-Test	15.4	3.79	10.66	2.96
Processing speed	Pre-Test	6.6	4.95	6.06	2.49
	Post-Test	11.4	4.1	6.86	3.56

Table 3 presented the descriptive statistics for math progress (mathematics grade) and the components of spatial understanding, working memory, and processing speed across both the Math educational Lego and control groups. The pre-test mean scores for math progress were similar between the groups, with the Lego group averaging 15.93 (SD = 2.18) and the control group averaging 15.26 (SD = 1.69). However, in the post-test, the Lego group showed a notable improvement with a mean score of 17.4 (SD = 1.91), compared to the control group, which had a mean of 15.33 (SD = 1.29). For spatial perception, the Lego group also demonstrated a significant increase from a pre-test mean of 15.66 (SD = 2.82) to a post-test mean of 19.73 (SD = 2.89), while the control group showed only a minor change from 14.2 (SD = 4.24) to 14.8 (SD = 4.09). The working memory scores reflected a similar pattern, with the Lego group's mean rising from 10.26 (SD = 2.96) in the pre-test to 15.4 (SD = 3.79) in the post-test, while the control group showed a smaller increase from 9.73 (SD = 2.98) to 10.66 (SD = 2.96). Processing speed also improved more substantially in the Lego group, with the mean score increasing from 6.6 (SD = 4.95) in the pre-test to 11.4 (SD = 4.1) in the post-test, compared to the control group's more modest rise from 6.06 (SD = 2.49) to 6.86 (SD = 3.56). These descriptive statistics indicated that the Lego-based educational program had a positive impact on math progress, spatial understanding, working memory, and processing speed compared to the control group.

Statistical test assumptions

To assess the assumption of normality for the variables, the Shapiro-Wilk test was used.

Table 4

Results of the Assumptions of Homogeneity of Variances and Normality of the Research Variables in The Post-Test Phase

Variable	Levin's test				Normality Test	
	F	df1	df2	P value	Statistic	P value
Math Progress	2.73	1	28	0.109	.89	.765
Spatial Understanding	1.76	1	28	0.195	.97	.921
Working Memory	0.811	1	28	0.376	.93	.877
Processing Speed	2.43	1	28	.129	.90	.866

The results indicated that, given the non-significance of the variables at the 0.05 level, the distribution of the variables is normal(P > 0.05). Levene's test was used to check the homogeneity of the error variance of the math achievement variable (math grade) and the components of spatial understanding, working memory, and processing speed in the post-test stage across two groups, with the results reported in Table 4. The results indicated that Levene's test was non-significant for the math achievement variable (math grade) and the components of spatial understanding, working memory, and processing speed in the post-test stage at the 0.05 level (P > 0.05). Therefore, the condition of homogeneity of between-group variances has been met for all research variables in the post-test stage, with no differences observed between them.

To check the homogeneity of the variance matrix of the Wechsler IQ components in the post-test stage, the M-box test was used, The results of the M-box test showed that the homogeneity of the variance matrix of the Wechsler intelligence components was confirmed at the 0.05 level across all levels of the independent variable (groups).

Interventional effects

The effectiveness of the math educational Lego intervention on the dependent variables was evaluated using ANCOVA and MANCOVA, with particular attention to ensure the assumptions for these analyses were met. These assumptions included normality, homogeneity of regression slopes, homogeneity of variances, homogeneity of the variance-covariance matrix, and the absence of multivariate outliers. The data were confirmed to be normal, with homogenous regression coefficients, variances, and variance-covariance matrices, and no multivariate outliers were detected.

Table 5

The Results of Univariate Analysis of Covariance to Investigate the Effectiveness of Math Educational Lego in Math Progress

Variable	Source	Sum of squares	df	Mean square	*F*	a	Effect size	Test power
Math progress	Modified pattern	32.08	2	1.04	5.78	0.00	0.29	0.9
	Pre-Test	0.05	1	0.05	0.02	0.88		
	Group	31.52	1	31.52	11.36	0.00		
	Error	74.87	27	2.77				

Table 5 provided the results of the univariate analysis of covariance, focusing on the math progress of first-grade students. After adjusting for pre-test scores as a covariate, the analysis revealed that the group variable (intervention vs. control) had a significant effect on math progress, as indicated by the F-value of 11.36 and a p-value of 0.00. This significant effect demonstrated a clear difference between the two groups in post-test math progress scores. The effect size (η^2) was calculated to be .29, indicating that approximately 29.6% of the variance in post-test math progress scores could be attributed to the intervention. Additionally, the statistical power of 0.9 suggested that the sample size was sufficient and the results were statistically robust. Overall, these findings indicated that the math educational Lego program significantly improved math progress in first-grade students compared to the control group, with the adjusted mean difference in post-test scores being 2.08.

Table 6 presented the results of the one-way analysis of covariance (ANCOVA) conducted to assess the effectiveness of the math educational Lego program on three components of cognitive functioning: spatial understanding, working memory, and processing speed in the post-test phase.

Table 6

One-Way Analysis of Covariance for Inter-Group Difference on Wechsler's Intelligence Components In The Post-Test

Component	Source	Sum of squares	df	Mean square	F	Sig.	Eta squared
Spatial perception	between groups	114.65	1	11.65	1.48	0.00	0.36
	error	197.85	25	7.91			
working memory	between groups	146.94	1	146.94	12.13	0.00	0.32
	error	302.81	25	12.11			
Processing speed	between groups	134.31	1	134.31	18.16	0.00	0.42
	error	184.85	25	7.39			

The analysis indicated significant differences between the intervention and control groups across all three cognitive components. For spatial understanding, the intervention group showed a significantly higher performance, as reflected by an F-value of 11.65 and a p-value of 0.00, with an effect size (Eta squared) of .36, indicating that 36% of the variance in spatial understanding could be attributed to the Lego-based intervention. Similarly, for working memory, the intervention group's performance was significantly superior, with an F-value of 12.13 and a p-value of 0.00, and an effect size of .32, suggesting that 32% of the variance in working memory was due to the intervention. Processing speed also showed a substantial improvement in the intervention group, with an F-value of 18.16, a p-value of 0.00, and an effect size of .42, indicating that 42% of the variance in processing speed could be linked to participation in the math educational Lego program. These results underscore the program's significant positive impact on enhancing the cognitive abilities of the first-grade students who participated in the intervention.

Discussion

The present study aimed to investigate the effectiveness of the "More to Math" educational Lego program on the mathematical progress, spatial understanding, working memory, and processing speed of first-grade female students in an elementary school setting. The findings from this research were particularly significant, addressing the growing need for innovative educational tools that could engage young learners and support cognitive development in foundational academic areas. Traditional teaching methods often struggle to captivate students and effectively nurture essential skills in mathematics. In contrast, the use of Lego in educational contexts, particularly within the "More to Math" program, offered a dynamic, hands-on approach that provided an engaging alternative. By integrating play-based learning into the curriculum, the program not only aimed to enhance students' mathematical abilities but also sought to improve other cognitive domains, such as spatial reasoning and memory functions, which are crucial for comprehensive learning.

The results of the study demonstrated that the "More to Math" program had a significant and positive impact on both the academic and cognitive development of these young learners. Specifically, the program markedly enhanced the students' mathematical progress, showing that hands-on, interactive learning tools could effectively reinforce and deepen their understanding of mathematical concepts. This was particularly important for first-grade students, who are in a critical stage of developing their foundational math skills. Additionally, the program significantly improved spatial understanding, suggesting that the physical manipulation of Lego bricks helped students better visualize and comprehend spatial relationships, which are foundational to geometry and other areas of math. Moreover, the study found that the program positively influenced working memory, indicating that the cognitive demands of building and problem-solving with Lego supported memory retention and mental processing. This enhancement of working memory is crucial as it underpins the ability to hold and manipulate information in mind over short periods, a skill essential not only for math but for learning across all subjects. Furthermore, the "More to Math" program significantly increased processing speed, demonstrating that the structured yet playful activities could enhance the students' ability to quickly and accurately complete cognitive tasks. Processing speed is a key cognitive skill that contributes to a student's ability to efficiently carry out mental operations, which is vital for academic performance, particularly in timed tasks.

These findings underscore the program's effectiveness not only in fostering mathematical skills but also in promoting a range of cognitive abilities essential for overall academic success. The results suggest that incorporating educational tools like the "More to Math" program into the curriculum can lead to a more holistic approach to early childhood education, where the development of multiple cognitive abilities is emphasized alongside core academic skills. This study contributes to a broader understanding of how educational interventions that combine physical manipulation with abstract thinking can positively impact the cognitive and academic growth of young learners, particularly in early education, where the cultivation of foundational skills is critical for future success. Ultimately, the research highlights the importance of using innovative and engaging educational tools to enhance the learning experience and cognitive development of young students.

These results were in line with previous studies. For example, a study conducted by Fengfeng Ke (2008) examined the impact of educational computer games on fifth-grade students' math learning outcomes. The study used a mixed-methods approach, comparing computer games with traditional paper-and-pencil drills across different classroom goal structures: individualistic, competitive, and cooperative. The findings showed that while computer games significantly improved students' learning motivation, they did not lead to better cognitive performance in math tests compared to traditional methods. However, a cooperative classroom goal structure enhanced the positive effects of computer games on students' attitudes towards math learning (Ke, 2008).

In a study conducted by Maria Meletiou-Mavrotheris (2012), the authors used a game-enhanced learning environment to train pre-service primary school teachers in mathematics. The study involved pre-surveys, interviews, and a teaching experiment where participants explored the use of online educational games in mathematics instruction. The results showed that while students had positive attitudes toward game-based learning, their understanding of its educational potential was initially limited. However, after the course, participants developed greater competence in selecting and effectively using online games as instructional tools.

The significant improvements observed in mathematical progress, spatial understanding, working memory, and processing speed among first-grade female students can be attributed to several key factors inherent in the "More to Math" educational Lego program. Firstly, the hands-on, tactile nature of Lego activities allows students to engage in active learning, which is known to enhance memory retention and conceptual understanding. This aligns with the principles of constructivist learning theories, such as those proposed by Piaget, who emphasized the importance of active exploration and manipulation of objects for cognitive development. The process of physically constructing mathematical models with Lego bricks likely helped students internalize mathematical concepts in a more meaningful way, as they were able to see and touch the abstract ideas they were learning. This tangible engagement bridges the gap between abstract mathematical symbols and their real-world applications, making it easier for young learners to grasp complex concepts. Moreover, the structured nature of the "More to Math" program provides a balance between guided instruction and creative exploration, which may explain the improvements in working memory and processing speed. The repetitive yet varied tasks involved in Lego-based learning encourage the development of automaticity—a cognitive process where repeated practice leads to quicker and more efficient information processing. This is particularly relevant in early education, where building foundational skills like addition, subtraction, and spatial reasoning requires frequent practice to achieve fluency.

Furthermore, the problem-solving aspects of the program, where students must plan, execute, and adjust their building strategies, likely contributed to the enhancement of executive functions, including working memory. These activities demand that students hold multiple pieces of information in mind, such as the design they envision and the steps needed to build it, thereby strengthening their working memory through continuous mental manipulation. The increase in processing speed observed in the study could also be attributed to the dynamic and interactive nature of Lego play, which requires students to make quick decisions and adjustments as they build, fostering cognitive flexibility and rapid information processing (Festus & Adeyeye, 2012). In a study conducted by Sri Rejeki et al., the authors used LEGO as a tool for learning fractions to investigate its effects on students' conceptual knowledge and attitudes toward mathematics. The results showed that using LEGO supported students' understanding of fractions, particularly in representing fractions as parts of a whole and performing operations like addition and multiplication. This was true for both high-ability and low-ability students, although low-ability students also improved their computational skills. The study also found that while LEGO increased students' motivation and engagement, some students were more focused on playing than learning, highlighting the need for clear pedagogical instructions from teachers (Rejeki et al., 2027).

Conclusions

The findings from this study offer compelling evidence of the "More to Math" educational Lego program's success in advancing various cognitive and academic skills among first-grade female students. The program's impact on mathematical progress, spatial understanding, working memory, and processing speed highlights its effectiveness as an educational tool. The underlying rationale for these positive outcomes can be attributed to the program's unique integration of play-based learning with cognitive tasks, making abstract mathematical concepts more tangible and accessible for young learners. The "More to Math" program distinguishes itself by blending play-based learning with cognitive tasks, an approach that aligns well with Vygotsky's theory of cognitive development. Vygotsky emphasized the importance of active engagement and social interaction in learning. By incorporating hands-on activities with Lego bricks, the program facilitates physical manipulation of objects, which enhances students' spatial reasoning—a critical skill closely linked to mathematical success. This tangible interaction with mathematical concepts helps bridge the gap between abstract ideas and concrete understanding, enabling students to better grasp complex concepts through direct experience.

Spatial reasoning, a crucial component of mathematical achievement, benefits significantly from the Lego program. Manipulating Lego bricks requires students to visualize and understand spatial relationships, which supports their development in geometry and other mathematical areas. This hands-on approach not only makes math more engaging but also aids in internalizing concepts at a deeper level. Additionally, the repetitive nature of building and problem-solving tasks likely contributes to improvements in working memory and processing speed. These tasks demand that students hold and manipulate information, practice recall, and process visual-spatial data quickly, thus enhancing their cognitive abilities. These findings are consistent with previous research that underscores the benefits of play-based and interactive learning methods. For instance, Buckle (2015) highlighted that educational Lego activities engage multiple senses, which helps strengthen working memory and supports learners in constructing their understanding of mathematical principles. Similarly, Uttal et al. (2013) found that spatial skill training, such as block building, leads to significant improvements in mathematical performance. The structured yet flexible nature of the "More to Math" program, which allows for repeated practice and immediate feedback, aligns with findings by Nouchi et al. (2016) and Pardina-Torner et al. (2019), who reported enhancements in cognitive functions like processing speed and working memory through educational games.

The broader implications of these findings are reinforced by studies on educational games and play therapy. For instance, Ziv et al. (2022) found that gamers demonstrated superior reaction times and working memory compared to non-gamers, while Gerling et al. (2012) showed that computer games significantly improve cognitive abilities, including working memory performance. Karmalian et al. (2018) similarly confirmed that child-centered play therapy effectively boosts working memory and processing speed. The "More to Math" program's use of Lego bricks as tangible representations of abstract mathematical concepts provides a three-dimensional understanding, which is crucial for developing spatial reasoning and cognitive flexibility. The tactile nature of Lego play necessitates continuous attention and concentration, which likely contributes to the observed improvements in cognitive abilities. As students interact with the physical objects and navigate through various challenges in the program, they are required to maintain focus, perceive spatial relationships, and recall information. This hands-on, multisensory approach fosters cognitive flexibility and resilience, allowing students to experiment with different strategies and solutions. The program's emphasis on problem-solving and creative thinking further reinforces these cognitive skills, facilitating a deeper and more resilient understanding of mathematical concepts.

In summary, the "More to Math" Lego program effectively enhances mathematical understanding and cognitive abilities in young learners by leveraging the power of play-based, hands-on learning. Its integration of spatial reasoning, problem-solving, and repetitive practice aligns with established research, demonstrating that interactive and engaging educational tools can significantly benefit cognitive development and academic performance.

Limitations and Future Directions

Despite the promising results of the current study, several limitations should be acknowledged. First, the study was conducted with a relatively small sample size, which may limit the generalizability of the findings to a broader population. The specific focus on female first-grade students also restricts the applicability of the results to other age groups or to male students. Second, the study relied on a short-term intervention, and while significant improvements were observed, it remains unclear whether these gains are sustained over the long term or how they might translate into other areas of academic achievement. Finally, the study did not account for the possible influence of external factors such as parental involvement, prior mathematical knowledge, or classroom environment, all of which could have impacted the results.

For future research, it would be beneficial to conduct studies with larger, more diverse samples, including students of different ages and genders, to assess the generalizability of the findings. Longitudinal studies could also provide valuable insights into the long-term effects of the "More to Math" program on cognitive and academic development. Additionally, future research should consider examining the impact of external factors such as parental support and classroom dynamics, as well as comparing the effectiveness of the "More to Math" program with other educational interventions. Exploring these areas would provide a more comprehensive understanding of the program's impact and its potential applications in various educational settings.

This study demonstrated that the "More to Math" educational Lego program significantly enhances mathematical progress, spatial understanding, working memory, and processing speed among first-grade female students. For education policymakers and educational psychologists, these findings suggest that incorporating play-based, hands-on learning tools into the early childhood curriculum can be an effective strategy for promoting both cognitive and academic development, thereby supporting students' long-term educational success.

Ethical considerations

Following the principles of research ethics

Ethical principles were fully observed in this research. All participants were aware of the research process, and their information was kept confidential.
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Conflicts of interest

Authors have no conflict of interests.

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