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The effects of the marble shapes digital game on preschoolers' geometric recognition

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Abstract

Purpose – This study addresses the limited empirical evidence on the effectiveness of digital game-based learning in supporting early childhood geometry development in Indonesian contexts. Specifically, it examines whether the Marble Shapes digital game can improve geometric shape recognition abilities among children aged 4–5 years.
Design/methods/approach – A quantitative approach was employed using a quasi-experimental one-group pretest and post-test design. The sample consisted of 18 children from Group A at Harapan Bunda Kindergarten, selected through saturated sampling. Data were collected using a nine-item performance-based assessment aligned with early childhood cognitive development indicators. Instrument validity was confirmed (CVI = 0.86), and reliability was acceptable (Cronbach's α = 0.79). Data were analyzed using SPSS, including normality testing (Shapiro–Wilk) and paired-sample t-tests.
Findings — The results showed that the data were normally distributed (pre-test Sig. = 0.973; post-test Sig. = 0.412). There was a substantial increase in mean scores from 15.94 (pre-test) to 28.44 (post-test). The paired-sample t-test indicated a statistically significant improvement ($t = 10.792$, $df = 17$, $p < 0.001$), suggesting that the intervention had a strong positive effect on children's geometric shape recognition abilities.
Research implications/limitations – However, the absence of a control group, small sample size, and short intervention duration limit causal generalization and internal validity. Despite these limitations, the findings indicate that developmentally appropriate digital games, when supported by teacher facilitation, can enhance early geometry learning.
Practical implications – This study suggests that educators can integrate digital game-based media as complementary tools to support cognitive development in early childhood education, particularly in introducing abstract concepts through interactive and engaging formats.
Originality/value – This study contributes to the literature by providing experimental evidence of the effectiveness of a specific digital educational game in improving geometric recognition skills among preschool children in Indonesia, offering a foundation for further research on digital learning interventions in early childhood settings.

Keywords: cognitive development, digital game-based learning, early childhood education, geometric shape recognition, Marbel Shapes.

Paper type: Research paper

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Introduction

Early childhood development is a critical period for the formation of cognitive abilities, particularly symbolic thinking, which includes recognizing numbers, letters, and geometric shapes. Children aged 4–5 years are in a crucial developmental stage in which they begin to interpret and represent their environment through symbols and visual patterns (Suryana, 2021; Rozana et al., 2020). At this stage, learning experiences must be concrete, engaging, and developmentally appropriate to support optimal cognitive growth. Geometry, as a foundational component of early mathematics, plays a significant role in developing children's abilities to classify, compare, and recognize patterns in their everyday environment. Basic geometric shapes such as circles, squares, and triangles are not only essential mathematical concepts but also closely connected to children's daily experiences (Farida et al., 2020; Sa'idah, 2021; Ulfa et al., 2020).

Despite its importance, many early childhood education settings still face challenges in providing effective and engaging learning media for introducing geometric concepts. Conventional instructional approaches often rely on teacher-centered explanations or static visual aids, which may not align with young children's learning characteristics (Suryana, 2021; Rozana et al., 2020). As a result, children's ability to recognize geometric shapes remains limited, as observed in Harapan Bunda Kindergarten, South Bulango District, where many children in Group A showed difficulties in identifying and classifying basic geometric forms. These challenges highlight the urgent need for more interactive and child-centered learning approaches that can better support early cognitive development.

In response to this need, digital educational games have emerged as promising tools for enhancing early childhood learning. From a theoretical perspective, Piaget's (1999) constructivist theory emphasizes that children actively construct knowledge through interaction with their environment, particularly through play and exploration. Children in the preoperational stage learn most effectively through visual and manipulative experiences. In addition, Mayer's (2020) Cognitive Theory of Multimedia Learning suggests that combining visual and auditory elements can enhance information processing by engaging dual cognitive channels. Digital learning applications, therefore, have the potential to provide meaningful learning experiences by integrating visual stimulation, interactivity, and immediate feedback in ways that align with children's developmental characteristics.

One example of such media is the *Marbel Shapes* digital game, an interactive educational application designed to introduce geometric concepts through activities such as recognizing, matching, and grouping shapes. Previous studies have indicated that digital learning media can support early cognitive development and increase children's engagement (Azizah & Salehudin, 2023; Setiawan et al., 2019; Sipahutar et al., 2023). However, much of the existing research remains descriptive or focuses broadly on the use of digital media without rigorously testing its effectiveness through experimental approaches (Azizah & Salehudin, 2023; Setiawan et al., 2019; Yulianto et al., 2025). Moreover, there is limited empirical evidence examining the specific impact of the *Marbel Shapes* application on geometric shape recognition skills in early childhood, particularly within the Indonesian educational context.

This gap is significant given the increasing integration of digital technology in early childhood education and the need for evidence-based learning tools. Without empirical validation, the adoption of digital games in classrooms risks being guided more by trends than by demonstrated effectiveness. Therefore, systematic investigation is necessary to determine whether such tools genuinely contribute to children's learning outcomes.

Based on this rationale, the present study aims to examine the effect of the *Marbel Shapes* digital game on the geometric shape recognition abilities of children aged 4–5 years at Harapan Bunda Kindergarten, South Bulango District. Specifically, this study seeks to provide empirical

evidence, through a quasi-experimental approach, of whether the use of this digital game can significantly improve children's ability to identify, name, match, and group geometric shapes.

The findings of this study are expected to contribute to the development of digital-based learning strategies in early childhood education and provide educators with a more evidence-based foundation for selecting appropriate instructional media. In addition, this study offers practical insights into how digital games can be effectively integrated into early childhood classrooms to support cognitive development in a structured and pedagogically meaningful way.

Methods

This study adhered to ethical research principles. Written permission was obtained from the school administration and parents or guardians of the participating children prior to data collection. Participation was voluntary, and all data was collected anonymously to ensure confidentiality. The research process was conducted with careful consideration of children's safety, comfort, and well-being throughout the intervention. This study employed a quantitative approach using a quasi-experimental method with a one-group pretest–posttest design to examine the effect of the *Marbel Shapes* digital game on children's geometric shape recognition abilities. This design allows for the observation of changes in participants' abilities before and after the intervention. Although the study did not include a control group, this approach was selected due to field constraints that did not permit the formation of an equivalent comparison group. The researchers acknowledged potential threats to internal validity, such as maturation and testing effects, and attempted to minimize these by limiting the time interval between pretest and posttest and by using systematically validated instruments.

The population of the study consisted of all children aged 4–5 years at Harapan Bunda Kindergarten, South Bulango District. A saturated sampling technique was applied, in which all members of the population were included as participants. The final sample comprised 18 children in Group A, consisting of 10 girls and 8 boys, with relatively homogeneous socioeconomic backgrounds.

The intervention utilized the Android-based *Marbel Shapes* educational application, which is designed to introduce basic geometric concepts through interactive activities. The treatment was conducted over eight learning sessions within a two-week period, with a frequency of four sessions per week, each lasting approximately 30–40 minutes. The learning activities included recognizing geometric shapes through animations, matching shapes using digital puzzles, grouping shapes based on their names and colors, and completing interactive quizzes provided within the application. Each session was facilitated by the classroom teacher in collaboration with the researcher, using digital tools such as tablets and projectors available at the school.

Data were collected using a performance-based test instrument designed to measure children's ability to recognize geometric shapes. The instrument consisted of nine items aligned with STPPA cognitive development indicators, covering skills such as identifying, pointing to, naming, matching, and grouping geometric shapes. Each item was assessed using a four-level developmental scale: *Belum Berkembang (BB)*, *Mulai Berkembang (MB)*, *Berkembang Sesuai Harapan (BSH)*, and *Berkembang Sangat Baik (BSB)*, which were converted into numerical scores ranging from 1 to 4.

The validity of the instrument was tested using Pearson correlation analysis. The results indicated that all items met the validity criteria, with calculated correlation values (r_calculated) exceeding the critical value (r_table = 0.468), thus confirming that all nine items were valid. The reliability of the instrument was assessed using Cronbach's Alpha, yielding a coefficient of 0.79, which indicates acceptable internal consistency.

The data collection procedure consisted of three stages. First, a pretest was administered to measure children's initial ability to recognize geometric shapes prior to the intervention. Second, the treatment phase was conducted using the *Marbel Shapes* digital game. Third, a posttest was administered after the intervention to assess changes in children's performance.

Data analysis was conducted using SPSS version 23. Descriptive statistics were used to summarize the data. A Kolmogorov–Smirnov test was performed to assess the normality of the data distribution. Hypothesis testing was carried out using a paired-sample t-test to determine whether there was a statistically significant difference between pretest and posttest scores. The level of significance was set at $p < 0.05$. The interpretation of the results was based on both statistical significance and the magnitude of observed changes.

This study adhered to ethical research standards. Permission was obtained from the school and the parents of the participating children prior to data collection. All data were collected anonymously and used solely for academic purposes, with careful attention to ensuring children's safety, comfort, and well-being during the research process.

Result

This study was conducted in three stages: pretest, treatment, and posttest. The pretest measured children's initial ability to recognize geometric shapes, the intervention used the *Marble Shapes* digital game, and the posttest evaluated learning outcomes.

Descriptive Statistic

The descriptive analysis shows an increase in children's ability to recognize geometric shapes. The mean score increased from 15.94 (pretest) to 28.44 (post-test).

Figure 1

Comparison of Mean Pretest and Posttest Scores

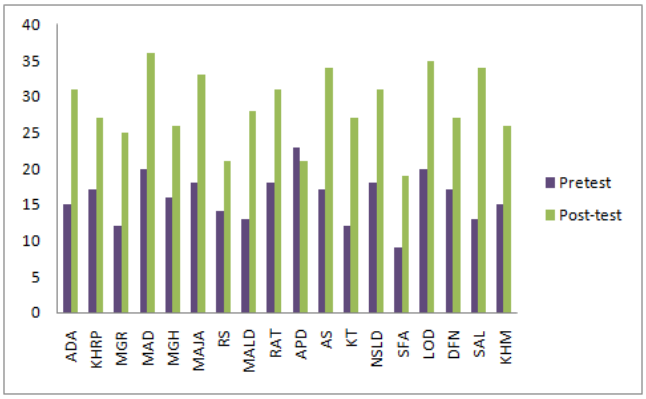


Figure 1 shows the comparison of mean scores between the pretest and posttest. The mean score increased from 15.94 in the pretest to 28.44 in the posttest. This substantial increase indicates that children demonstrated improved performance in recognizing geometric shapes after participating in the game-based learning intervention. The difference suggests that the treatment had a strong positive impact on learning outcomes.

Figure 2

Comparison of Total Pretest and Posttest Scores

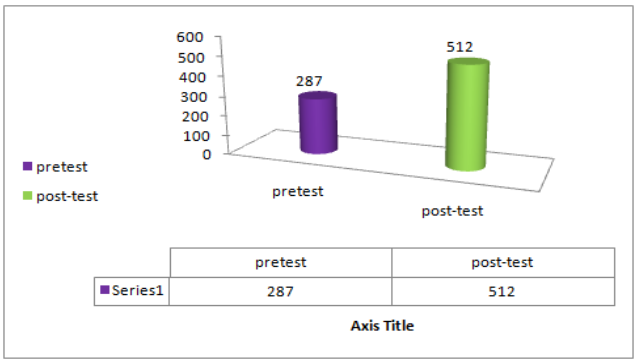


Figure 2 presents the comparison of total scores obtained by all participants. The total score increased from 287 (pretest) to 512 (post-test). This overall increase reflects a consistent improvement across participants rather than isolated gains. It indicates that most children benefited from the intervention.

Table 1

Descriptive Statistics for Pretest and Posttest Score

Statistic	Pre-test	Post-test
Mean	15.94	28.44
Standard Deviation	3.438	5.044
Minimum	9	19
Maximum	23	36
Range	14	17
Interquartile Range	5	8
Median	16.50	27.50

Table 1 shows the descriptive statistics of children's geometric shape recognition scores before and after the intervention. The increase in the mean score from 15.94 to 28.44 confirms overall improvement. The higher post-test standard deviation (5.044) compared to the pretest (3.438) indicates greater variability in children's performance after the intervention, suggesting that while most children improved, the degree of improvement differed among individuals. The increase in minimum and maximum scores also shows that both lower-performing and higher-performing children experienced progress.

Normality Test

Table 2

Normality Test Results

Test	Statistic	df	Sig.
Pretest (Kolmogorov–Smirnov)	.121	18	.200
Posttest (Kolmogorov–Smirnov)	.138	18	.200
Pretest (Shapiro–Wilk)	.983	18	.973
Posttest (Shapiro–Wilk)	.949	18	.412

Table 2 presents the results of the normality test. The significance values for both pretest and post-test scores are greater than 0.05, indicating that the data are normally distributed. This confirms that the assumptions for parametric statistical testing were met, allowing the use of the paired-sample t-test for hypothesis testing.

Hypothesis Testing

Table 3

Paired-Sample Statistics

Variable	Mean	N	SD	SE
Pretest	15.94	18	3.438	0.810
Posttest	28.44	18	5.044	1.189

Table 3 shows the comparison of mean scores between pretest and posttest for the same group of participants. The increase in mean scores from 15.94 to 28.44 indicates a notable improvement in children's geometric shape recognition ability following the intervention.

Table 4

Paired-Sample t-Test Results

Measure	Value
Mean Difference	12.500
Standard Deviation	4.914
Std. Error Mean	1.158
t	10.792
df	17
Sig. (2-tailed)	.000

Table 4 presents the results of the paired-sample t-test. The mean difference between pretest and posttest scores is 12.500, with a t-value of 10.792 and a significance level of 0.000 ($p < 0.05$). These results indicate a statistically significant improvement in children's geometric shape recognition ability after the intervention. Therefore, the hypothesis that the *Marbel Shapes* digital game improves geometric recognition skills is supported.

Discussion

This study examined the effect of the *Marbel Shapes* digital game on the geometric shape recognition abilities of children aged 4–5 years. The findings indicate a statistically significant improvement in children's performance following the intervention. While these results demonstrate the effectiveness of the digital game, a deeper analysis is necessary to understand the mechanisms underlying this improvement and to position the findings within broader international research on digital game-based learning.

From a constructivist perspective, the observed learning gains are consistent with Piaget's view that children actively construct knowledge through interaction with their environment. The *Marbel Shapes* application facilitates this process by allowing children to engage in classification, matching, and symbolic representation tasks, which are essential for early mathematical development (Sa'idah, 2021; Isran, 2018). These findings are also supported by recent international research showing that well-designed mobile educational applications can significantly enhance preschoolers' geometric cognition and support knowledge transfer (Wang & Wei, 2025).

The effectiveness of the intervention can also be explained through Mayer's Cognitive Theory of Multimedia Learning, which highlights the importance of dual-channel processing in enhancing understanding. The integration of visual animation, audio instructions, and interactive feedback in the *Marbel Shapes* game enables children to process information through both visual and auditory channels, thereby improving retention and comprehension (Hamida & Aulina, 2021). Recent studies further confirm that interactive multimedia environments improve learning by combining engagement, feedback, and multimodal input, which collectively enhance cognitive processing and conceptual understanding.

Another important factor contributing to the improvement is the game-based learning structure, which incorporates repetition, challenge, and immediate feedback. These elements are known to support deeper learning and motivation. Contemporary research indicates that digital educational games provide challenge-based environments that reinforce concepts through active exploration and feedback loops, thereby strengthening conceptual clarity and long-term retention (Mayer, 2020; Debrenti, 2024). This aligns with the present findings, where repeated interaction with geometric tasks likely enhanced children's ability to discriminate and categorize shapes.

However, the results should not be interpreted solely reflecting the effectiveness of the digital game itself. The observed improvement is more accurately understood as the result of an interaction between media design, learner engagement, and instructional support. Research in digital mathematics learning emphasizes that technology does not automatically improve learning outcomes; rather, its effectiveness depends on how it is integrated into pedagogical practice and how it supports active participation (Sinclair & Yerushalmy, 2016). This is consistent with the current study, where teacher facilitation played a crucial role in guiding children's engagement with the digital media (Setiawan et al., 2019; Azizah & Salehudin, 2023).

The increase in posttest standard deviation also suggests heterogeneity in learning outcomes, indicating that children responded differently to the intervention. This variability may be influenced by factors such as prior knowledge, digital familiarity, attention span, and individual learning preferences. Previous studies similarly highlight that digital learning environments produce differentiated effects across learners, particularly in early childhood settings where developmental differences are pronounced (Farida et al., 2020; Rozana et al., 2020). Therefore, while the intervention was generally effective, it may require adaptation to better support diverse learners.

From a broader perspective, this study contributes to the growing body of evidence suggesting that digital game-based learning can support early mathematical development when designed appropriately and implemented pedagogically. A recent systematic review also highlights that digital game-based learning has strong potential to foster cognitive skills and critical thinking, although outcomes vary depending on game design and instructional context (Yulianto et al., 2025). This reinforces the importance of not only adopting digital tools but also critically evaluating their design and implementation.

In conclusion, the findings suggest that the *Marbel Shapes* digital game can serve as an effective instructional medium for improving geometric shape recognition in early childhood education. However, its effectiveness should be understood as the result of a synergistic relationship between digital media design, repeated practice, and teacher-guided learning, rather than as an isolated technological effect.

Research Contribution

First, this study offers empirical evidence on the effectiveness of the *Marbel Shapes* digital game in improving geometric shape recognition abilities among children aged 4–5 years. While previous studies have discussed the potential of digital media in early childhood learning, many remain descriptive in nature. This study strengthens the evidence base by demonstrating statistically significant learning gains through a quasi-experimental approach, particularly within the Indonesian early childhood education context, which remains underrepresented in international research.

Second, this study contributes to the theoretical understanding of how digital learning supports early cognitive development. The findings reinforce constructivist perspectives that emphasize active learning through interaction, as well as multimedia learning principles that highlight the role of visual and auditory integration in enhancing comprehension. By linking these theoretical frameworks to measurable learning outcomes, this study provides a clearer explanation of how interactive digital environments facilitate early mathematical concept acquisition.

Third, this study provides practical contributions for educators by demonstrating that digital games can be effective learning tools when implemented within structured and guided instructional settings. The findings suggest that the effectiveness of digital learning does not solely depend on the technology itself, but rather on the interaction between game design, repeated practice, and teacher facilitation. This offers a practical foundation for integrating digital media into early childhood classrooms in a pedagogically meaningful way.

Limitations

Despite these contributions, several limitations must be acknowledged. The use of a one-group pretest–posttest design without a control group limits causal interpretation. The observed improvements may be influenced by maturation, testing effects, or increased familiarity with the assessment tasks. In addition, the novelty effect of using digital media may have temporarily increased children's motivation, potentially inflating short-term gains. Furthermore, the study focused exclusively on geometric shape recognition, and therefore the findings cannot be generalized to broader cognitive or mathematical domains.

Recommendations/Implications

Future research should address these limitations by employing controlled experimental designs, larger and more diverse samples, and longer intervention periods to examine the sustainability of learning outcomes. It is also important to explore how different design features—such as interface type, level of interactivity, and feedback mechanisms—affect children's learning processes.

From a practical perspective, the findings suggest that digital educational games such as *Marbel Shapes* can be effectively integrated into early childhood learning environments as complementary instructional tools. However, their effectiveness depends on structured implementation and active teacher involvement. Educators should guide children's interactions, provide scaffolding, and ensure that the use of digital media aligns with learning objectives. The use of digital games can support engagement and repeated practice, which are essential for mastering abstract concepts such as geometric shapes. Therefore, teachers are encouraged to select developmentally appropriate applications that combine visual clarity, interactivity, and feedback.

At a broader level, the findings highlight the importance of supporting evidence-based integration of digital media in early childhood education. Educational institutions and policymakers should not only promote access to digital tools but also provide professional development opportunities for teachers to effectively implement digital learning strategies. The results also suggest that digital game-based learning should be viewed not as a replacement for traditional teaching methods, but as a pedagogical enhancement that, when properly designed and implemented, can support children's cognitive development in meaningful ways.

Conclusion

This study demonstrates that integrating the *Marbel Shapes* digital game into guided classroom activities is associated with improved geometric shape recognition among children aged 4–5 years. Following the intervention, children showed enhanced ability to identify, name, match, and group geometric shapes, indicating that structured digital game-based learning can support early geometry development.

The findings suggest that developmentally appropriate digital games can serve as effective complementary tools in early childhood education when implemented purposefully. Their effectiveness, however, depends on active teacher facilitation, clear instructional goals, and integration with broader play-based and hands-on learning experiences. Accordingly, digital games should be positioned as pedagogical support rather than replacements for teacher-led instruction.

Declarations

Author contribution statement

Conceptualization, methodology, data collection, formal analysis, writing – original draft (SN&IS). Validation, data interpretation, writing, review & editing (ST&NA). Supervision, manuscript review, and final approval of the manuscript (S).

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Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available to preserve the integrity of the research and to ensure their appropriate use in accordance with academic and ethical standards. Relevant data may be provided to qualified researchers for the purposes of verification or further scientific investigation, subject to a reasonable request.

Declaration of interest's statement

The author(s) declare that they have no known competing financial interests, professional affiliations, or personal relationships that could have appeared to influence the work reported in this manuscript. Furthermore, the research was conducted independently without any external influence that could give rise to a potential conflict of interest.

Declaration of using AI (Artificial Intelligent)

The author(s) used Artificial Intelligence (AI) tools solely to assist with language editing, grammar refinement, improvement of writing clarity, and organization of the manuscript. AI tools were not used to generate research data, perform scientific analyses, interpret research findings, or formulate the conclusions of this study. The intellectual content, research design, methodology, data analysis, interpretation of results, and conclusions are entirely the responsibility of the author(s). The author(s) carefully reviewed and verified all AI-assisted outputs before submitting the manuscript for publication.

Additional information

This study was conducted as an independent research project to contribute to the advancement of knowledge in the relevant field. All aspects of the research, including conceptualization, methodology, data collection, analysis, interpretation of results, and manuscript preparation, were carried out solely by the author(s) without external financial support. The author(s) are committed to maintaining the highest standards of research integrity, transparency, and ethical conduct throughout the research process. Additional information or supporting materials may be obtained from the corresponding author upon reasonable request for academic purposes or scientific verification.

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