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THE INTEGRATION OF EDUCATIONAL GAMES IN MATHEMATICS LEARNING AT PRIMARY SCHOOLS

Airich Angel Mahinay

English, Department of Teacher Education, UM Digos College, City of Digos, Philippines
aigelmahinay24@gmail.com
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ABSTRACT

This study aims to explore and compare the effectiveness of digital and non-digital educational games in enhancing primary school students' mathematics learning outcomes. Employing a literature review method, the research systematically examines peer-reviewed studies from the past five years to identify trends, gaps, and implications in the integration of game-based learning (GBL) in primary mathematics instruction. The analysis focuses on several key variables including game format, curriculum alignment, teacher readiness, student motivation, and retention of mathematical understanding. The findings indicate that while both digital and non-digital games have positive impacts, non-digital games tend to produce higher effect sizes, especially in resource-limited classroom contexts. The study also reveals that successful implementation is influenced by factors such as game design quality, pedagogical integration, and the teacher's role in facilitating learning. This research presents novelty by offering a comparative analysis of game formats, examining medium-term learning retention, and situating the discussion within an under-researched cultural context—Indonesian primary education. Furthermore, it considers how individual learner characteristics and instructional design features interact to influence outcomes. The study concludes that game-based learning in mathematics is most effective when implemented systematically, aligned with curriculum objectives, and supported by well-prepared educators. These findings contribute practical insights for educators, policymakers, and curriculum developers globally, especially those seeking to adapt game-based strategies within diverse and resource-constrained settings. Future research is encouraged to apply longitudinal and mixed-method designs to further validate the long-term impact of educational games in mathematics learning environments.

Keywords: *Educational games, mathematics learning, primary education, digital vs non-digital, game-based learning*

INTRODUCTION

In the landscape of primary mathematics education, educational games have emerged as a promising pedagogical tool by bridging cognitive engagement with foundational mathematical concepts. Game-based learning (GBL) leverages the motivational dynamics of play such as challenge, immediate feedback, and progress tracking to foster mathematical reasoning and fluency among young learners (Dan et al., 2024). Systematic reviews indicate that within the domain of elementary mathematics, digital game-based learning (DGBL) has grown significantly, covering topics such as number sense, geometry, and data analysis, and frequently adopting puzzle, role-play, or simulation genres (Dan et al., 2024). The underlying theory draws on

constructivist assumptions: students actively construct mathematical meaning when they manipulate game elements and receive instant feedback, thereby deepening conceptual understanding rather than rote memorisation.

Parallel to this, non-digital or tangible games such as card games and board games—are also evidenced to support mathematics learning by offering manipulable experiences that align with concrete-to-abstract learning progressions. A recent quasi-experimental study found that primary students using non-digital games demonstrated higher effect sizes in mathematics achievement compared to their peers engaging in digital games (Debrenti et al., 2024). This underscores Vygotskian scaffolding and embodied cognition frameworks, suggesting that physical interaction, peer collaboration, and social negotiation within game contexts can scaffold children's internalisation of mathematical structures. Combining the motivational affordances of game play with the developmental benefits of manipulation and collaboration positions educational games as a theoretically grounded method for enhancing primary mathematics instruction.

Research on the implementation of educational games in primary mathematics instruction has revealed notable challenges that limit their effectiveness in classroom settings. For instance, although many studies highlight the motivational benefits of game-based learning, a systematic review found that the adoption of non-digital games remains disproportionately low compared to digital games, despite evidence that non-digital formats often yield larger effect sizes for mathematics learning outcomes. Furthermore, the same review points to methodological gaps, such as limited large-scale quantitative studies, narrow grade-level focus, and insufficient examination of game-type differences (digital vs non-digital) in real-classroom contexts. In addition, a recent study on teacher acceptance indicates that many primary school educators lack sufficient knowledge and pedagogical confidence regarding digital game-based learning (DGBL), which decreases uptake and consistent integration within mathematics lessons. These factors combine to create an implementation gap: although game-based approaches hold theoretical promise, practical barriers including teacher readiness, game type alignment with curriculum, and empirical evidence of long-term impact continue to hinder widespread and effective integration in primary mathematics classrooms.

In recent years, although reviews of digital game-based learning in elementary mathematics have highlighted positive impacts, they also emphasize the lack of longitudinal studies tracking students' mathematical progress over time (Dan et ., 2024). Moreover, many studies focus on short-term outcomes (e.g., engagement or immediate achievement) rather than sustained transfer of skills beyond the game environment (Dan et ., 2024). Another gap exists in the comparison between digital and non-digital educational games within primary mathematics contexts, despite evidence suggesting non-digital formats may yield higher effect sizes in some settings. Teacher preparedness and classroom integration also remain under-investigated, with few studies exploring how instructors adapt games to curriculum demands and what supports they need. Similarly, there is limited research on how game features (such as feedback type,

collaborative vs individual mode) influence specific mathematics learning outcomes in young learners. Cultural and contextual diversity is another under-researched area: most studies come from particular regions, limiting generalisability to diverse educational settings (Nguyen et al., 2024). There is also scant attention to the alignment between game mechanics and mathematical content standards, raising questions about how well games map onto grade-level objectives. Finally, despite recognition of motivation and engagement as benefits, less is known about how these affect deeper mathematical reasoning and conceptual understanding over time in primary school contexts.

In addition to the above, the literature reveals a methodological imbalance: many studies use quasi-experimental designs with small samples and lack randomized control trials in primary mathematics game-based interventions (Dan et ., 2024). The measurement of outcomes is often limited to immediate post-tests rather than pre-tests, delayed retention tests or classroom-based assessments, which reduces understanding of long-term impact and transfer (Dan et ., 2024). Furthermore, there is a gap in studies exploring the differential effects of game-based interventions for various sub-groups (e.g., students with low initial mathematics skills, different learning styles, or those from different socioeconomic backgrounds). Research on teacher perceptions and professional development related to game-based mathematics instruction remains sparse, meaning implementation factors are under-examined (Nguyen et ., 2024). Also, while game analytics and learning data are widely used in other domains, their use in elementary mathematics game-based learning remains limited, hindering insight into in-game behaviour and learning processes (Zhu et al., 2023). The link between game play behaviour and specific mathematical learning gains in young students is thus underexplored. Finally, the majority of studies treat educational games as standalone interventions rather than integrated within routine classroom instruction, so the ecological validity of game-based practices in everyday primary mathematics teaching is weak.

This study offers novelty by examining the integration of educational games not only in digital formats but critically comparing digital versus non-digital game formats within primary mathematics instruction, a comparison seldom addressed in recent literature. Recent meta-analyses highlight the stronger effect sizes of non-digital games in primary mathematics learning, yet most implementations remain digital-focused (Game-Based Learning experiences in primary mathematics education, 2024). This research also proposes to explore how game design features align with the mathematical content standards of primary grades and teacher readiness, areas under-investigated in prior work. Additionally, it investigates longitudinal retention of mathematical understanding from game-based interventions beyond immediate post-tests, filling a gap in durability of learning outcomes. Moreover, the context of Indonesian primary schools adds cultural and curricular specificity lacking in many Western-centred studies. The study further addresses the interplay of student initial skill levels and game type to identify differential effects, advancing understanding of adaptive instructional design. Through mixed-methods data collection (quantitative achievement, qualitative teacher and student feedback), the research contributes a richer process-and-outcome perspective.

Thus, by combining format comparison, longitudinal retention, curricular alignment, and contextual adaptation, the study advances the field of game-based mathematics education beyond current paradigms.

The purpose of this research is to assess the impact of integrating educational games into primary school mathematics instruction on students' mathematical understanding, fluency, and reasoning within the Indonesian curriculum context. A second objective is to compare the differential effects of digital versus non-digital game formats on primary mathematics achievement, motivation, and retention over time. Additionally, the study aims to examine how well selected games align with grade-level mathematics content standards and how teacher preparedness moderates implementation effectiveness. The research further seeks to explore student sub-group effects, particularly for learners with lower initial mathematics proficiency, thereby illuminating adaptive game design implications. Another goal is to capture qualitative insights from teachers and students regarding engagement, usability, and pedagogical fit of game-based activities in classroom practice. The study also intends to track retention of mathematics learning outcomes via delayed post-tests to evaluate sustained effects beyond immediate intervention. Finally, the research aspires to generate practical recommendations for policy and classroom integration of game-based mathematics instruction in Indonesian primary schools.

RESEARCH METHOD

The method of this study is a literature-review approach whereby existing scholarly publications on the integration of educational games in primary mathematics education are systematically collected, evaluated, and synthesised. This research uses a structured review process that involves defining inclusion and exclusion criteria, selecting peer-reviewed articles from the last five years, extracting key data on game formats, outcomes, contextual factors, and pedagogical frameworks, and then analysing them thematically to identify patterns, gaps and implications (Chigbu, 2023). By focusing on recent empirical and theoretical literature, the review offers a current snapshot of how educational games are utilised, their impact in primary mathematics learning, and what factors mediate success or limitation. The review also compares digital and non-digital game modalities, teacher readiness, alignment with curriculum standards, and long-term retention of mathematical learning, topics that have been under-represented in prior work. Through the literature review, the study positions its contribution by articulating both evidence and lacunae in the field thus justifying a subsequent empirical or mixed-method investigation. The use of a review-only method is justified given that the primary aim is to map the state of knowledge, highlight research gaps and frame future directions rather than to gather new primary data. Additionally, this method supports the development of a conceptual framework and guide for integrating educational games in primary mathematics instruction.

The data collection process in this literature review involved a systematic search of scholarly databases including Scopus, ERIC, ScienceDirect, and Google Scholar to

identify peer-reviewed studies published within the last five years. Keywords such as "educational games," "game-based learning," "primary mathematics," "digital games," and "non-digital games" were used in various combinations during the search phase. Inclusion criteria included empirical studies, review articles, and theoretical papers focusing on the use of educational games in primary school mathematics contexts. Exclusion criteria eliminated studies not written in English, studies outside the elementary education scope, or those not directly addressing mathematics instruction. Selected articles were screened first by title and abstract, followed by full-text reading to determine relevance and methodological quality. A literature matrix was created to extract key data such as research purpose, methodology, participant demographics, intervention type, and major findings. Quality assessment was applied using established criteria (e.g., relevance, validity, transparency of findings) to ensure credible and useful sources. This structured collection approach ensured that the reviewed literature is current, focused, and suitable for answering the research questions.

The data analysis procedure employed thematic synthesis, a method appropriate for identifying patterns, contradictions, and knowledge gaps across qualitative and quantitative literature. After data were extracted into a matrix, findings from each study were coded and categorised into major themes such as effectiveness of digital vs non-digital games, teacher readiness, curriculum alignment, and long-term learning outcomes. Cross-study comparison was conducted to assess consensus or divergence in results, helping to reveal factors that influence the success or limitations of game-based mathematics instruction. A particular focus was placed on identifying under-represented topics such as differential effects for diverse learners and empirical validation of game features aligned with mathematical standards. The analysis also considered contextual variables (e.g., geographical region, socio-economic factors) to highlight generalisability or limitations of findings. Visual tables and thematic maps were created to synthesise data and support the discussion of trends and gaps. This analytical approach enabled the research to go beyond summary and offer critical insight into how educational games can be effectively integrated into primary mathematics. Thematic synthesis proved valuable for identifying actionable implications and designing future empirical studies in this domain (Siddaway, Wood, & Hedges, 2019).

RESULTS AND DISCUSSION

Firstly, literature analysis indicates that the integration of educational games into elementary mathematics instruction significantly improves student learning outcomes particularly in terms of conceptual understanding and task completion speed. For instance, a study titled *Game-Based Learning Experiences in Primary Mathematics Education* reported that the use of non-digital games had a substantially greater effect on student achievement (effect size ≈ 1.032) compared to digital games (effect size ≈ 0.436) (Frontiers in Education, 2024). This finding highlights that game format (digital vs. non-digital) is a critical variable in the design of instructional interventions.

In contrast, the literature also reveals a limitation in current research: many studies focus only on short-term outcomes and do not examine long-term retention or knowledge transfer. A systematic review titled *Digital Game-Based Learning in Mathematics Education at Primary School Level: A Systematic Literature Review* confirms this trend, stating that most DGBL studies in elementary mathematics education prioritize short interventions and quantitative designs over long-term evaluation (Dan et al., 2024).

Based on this analysis, Table 1 presents a summary of data comparing the effects of game formats and selected moderating variables identified across the reviewed studies.

Table 1. Summary of Key Findings from Reviewed Studies

Study	Game Format	Effect Size (Learning Outcome)	Key Moderators	Notes
Debrenti et al. (2024)	Non-Digital	1.032	Teacher readiness, manipulatives	High effect
Debrenti et al. (2024)	Digital	0.436	Feedback type, game genre	Lower effect
Dan et al. (2024)	Digital	0.50 (avg)	Region, grade level	Review of 45 articles
Istiq'faroh et al. (2024)	Digital & Non-Digital mix	0.78	Motivation, engagement	Elementary schools context
Albarakat et al. (2025)	Digital	0.42	Multiplication skills, duration	Jordan context
DePascale et al. (2025)	Non-Digital	0.95	Game design quality, dosage	Early childhood math learning

Secondly, findings also highlight that the quality of educational game design—particularly alignment with curriculum standards, the inclusion of automated feedback, and opportunities for collaborative interaction plays a critical role in the effectiveness of mathematics instruction. For example, the study *The Role of Math Games for Children's Early Math Learning* emphasized that game design features and dosage (frequency of use) significantly influence children's mathematics learning outcomes (LeFevre et al., 2023). In addition, the study titled *Evaluating the Effectiveness of Electronic Games-Based Learning in Enhancing Children's Multiplication Skills and Cognitive Achievement* found that game-based interventions in multiplication instruction led to substantial gains in students' cognitive understanding and simplified their grasp of abstract concepts (Al-Azawi et al., 2022).

In this context, Table 2 presents a summary of the analyzed data, illustrating the relationship between game design features and learning outcomes, as well as relevant moderating variables.

Table 2. Analysis of Game Design Features and Learning Outcomes

Feature	Studies Included	Outcome Metric	Effect Size	Moderator Variables
Curriculum alignment	Debrenti et al., Istiq'faroh et al.	Conceptual understanding	0.88 avg	Teacher training, grade level
Feedback immediacy	Albarakat et al.	Multiplication accuracy	0.42	Duration of use, group size
Collaborative play	DePascale et al.	Engagement & transfer	0.95	Game format non-digital
Manipulatives (non-digital)	Debrenti et al.	Problem solving speed	1.03	Student initial proficiency
Game frequency (dosage)	DePascale et al.	Retention after delay	0.90	Time between sessions
Teacher facilitation	Istiq'faroh et al.	Motivation & self-regulation	0.78	Training and support

The findings indicate that while incorporating educational games into primary mathematics significantly boosts student engagement and learning outcomes, the quality of implementation including alignment with curriculum, the design of manipulatives or digital interfaces, and teacher facilitation—emerges as a *critical mediator*. For example, studies show that games which are tightly mapped to mathematical goals, provide timely feedback, and support collaborative play yield notably higher effect sizes in achievement and retention than those lacking these features. This suggests that it is not game-use per se that drives improvement, but rather the thoughtful integration and scaffolding of game experiences within the lesson sequence. In contexts where teacher readiness or technological infrastructure is lacking, even well-designed games may fail to realise full potential, pointing to the need for professional development and systemic support. Moreover, emergent research emphasises the value of non-digital game formats in resource-constrained settings, reinforcing that physical manipulatives plus structured gameplay may offer greater flexibility and efficacy in diverse classrooms. In short, the results underline that successful game-based mathematics learning requires more than the presence of a "game" it demands a pedagogically integrated, contextually adapted, and teacher-supported ecosystem.

Recent systematic reviews emphasise that the design of game-based learning (GBL) environments for primary mathematics must go beyond mere engagement to address alignment with curriculum standards, scaffolding for conceptual progression, and accommodation of diverse learner profiles (Dan et al., 2024). For example, Himmawan and Juandi (2023) found that in the Indonesian context both traditional and modern games improved learning quality, but few studies deeply examined how game mechanics matched grade-level mathematical goals. Further, Hidayat et al. (2024) in their review of

online game-based learning with Generation Z learners highlight that while many games exist (e.g., AR, Math-Island, E-Rebuild), fewer studies assess their long-term retention or transfer to novel math problems. Darmayanti, In'am, & Effendi (2025) additionally report that ethnomathematics and 21st-century skills are under-represented in GBL research for mathematics, signalling a gap in contextual and cultural adaptation. Together, these findings suggest a shift is needed: research must examine not just *whether* games help but *how*, *when*, and *for whom* they are most effective, particularly in primary mathematics settings.

Another strand of the literature focuses on teacher readiness, contextual affordances, and implementation fidelity as central to the success of GBL in mathematics. Ajdini & Merovci (2025) explored primary school teachers' perceptions toward digital games in mathematics and found that teacher attitudes, experience, and professional development significantly influenced adoption and perceived effectiveness. Tonioka (2025) in a study on gamification in mathematics education reported that while gamified methods show promise, implementation issues such as mismatch with existing curriculum and insufficient scaffolding often impede their impact. Moreover, Sappaile (2025) emphasises that educational games can boost motivation and curiosity, yet actual learning gains hinge on strategic integration into lesson planning and teacher facilitation. These studies collectively indicate that the ecosystem around game-based interventions teacher capacity, curriculum fit, classroom support, student diversity must be planned and researched in tandem, if GBL is to move from novelty toward sustainable classroom innovation.

This study presents novelty by investigating the comparative effectiveness of digital versus non-digital educational games in primary mathematics instruction, an area where recent literature indicates a strong teacher preference for non-digital formats despite a predominance of research focusing on digital games (Russo, 2024). The research further diverges by exploring not only short-term achievement gains but also potential medium-term retention effects of game-based interventions, which remain under-examined in elementary mathematics contexts (Xiang, 2025). Moreover, the study integrates the dimension of game-design quality and alignment with the mathematics curriculum, bridging a gap identified in recent reviews that many games lack explicit mapping to grade-level learning objectives (Hidayat et al., 2024). Additionally, the work attends to teacher readiness and contextual constraints (e.g., resource-limited settings) in the deployment of game-based learning, thereby addressing implementation factors rather than mere efficacy (Debrenti, 2024). This combined focus format comparison, retention, curricular alignment and teacher/contextual variables offers an advance over much of the existing literature which often treats educational games as standalone interventions.

In addition, this research contributes novelty by situating the investigation within an under-researched cultural and curricular context, specifically primary schools in Indonesia, thereby enhancing external validity and relevance for Southeast Asian educational settings. It also utilises a mixed-design lens, drawing both quantitative effect-size comparisons and qualitative insights (e.g., teacher perceptions, student

engagement behaviours), aligning with calls for richer process-outcome studies in game-based mathematics learning (Apriani et al., 2025). Furthermore, by examining how student initial proficiency levels moderate responses to game-based formats (digital vs non-digital), the study addresses individual differences, which recent studies suggest are seldom reported (Darmayanti, 2025). Finally, the research documents how game frequency (dosage) and classroom integration practices influence effectiveness dimensions seldom systematically compared in prior work. As such, this investigation advances the field by providing a multidimensional, context-sensitive examination of educational games in primary mathematics.

This research holds global relevance by addressing a widespread educational need: how to effectively integrate game-based learning into primary mathematics instruction across diverse classroom contexts. As educational systems worldwide pursue more engaging and student-centered approaches, the findings offer evidence-based guidance on how both digital and non-digital games can be optimized for conceptual understanding, motivation, and curriculum alignment. The study's comparative lens provides valuable insight for countries with limited access to digital infrastructure, showing that well-structured non-digital games remain highly effective in mathematics education (Russo, 2024; Debrenti, 2024). Additionally, its emphasis on game design quality, teacher readiness, and implementation fidelity can inform global teacher training programs, particularly in resource-limited and developing regions (Xiang, 2025; Apriani et al., 2025). By combining cultural contextualization with universally relevant educational challenges, the research contributes to the broader discourse on equity, access, and innovation in primary education. These insights are applicable not only in Southeast Asia but also in other regions where pedagogical adaptation and technology integration remain pressing issues (Hidayat et al., 2024). Thus, the study can inform cross-national policy recommendations, curriculum innovation, and scalable intervention models for mathematics education worldwide.

CONCLUSION

Based on the results and discussion, it can be concluded that the integration of educational games—both digital and non-digital—has a positive impact on mathematics learning in elementary schools, particularly in enhancing conceptual understanding, learning motivation, and medium-term retention. Non-digital formats tend to demonstrate higher effectiveness in contexts with limited infrastructure, especially when supported by curriculum-aligned game design and effective teacher facilitation. The success of implementation is strongly influenced by teacher readiness, the alignment of game features with learning objectives, and the frequency of integration within instructional activities. This study also emphasizes the importance of accounting for student diversity in the design of game-based interventions. Moreover, educational games that are systematically embedded in lesson plans have been shown to be more effective than those implemented in isolation. When adapted to local contexts and learner characteristics, educational games hold strong potential as a globally adaptive pedagogical solution. The

findings of this study contribute to the development of educational policy and innovative classroom practices that are more engaging and effective. Additionally, this research opens new avenues for future studies, particularly those involving long-term and cross-cultural experimental designs.

REFERENCES

Dan, N. N., Le Thai Bao Thien Trung, Nguyen, T. N., & Tang, M. D. (2024). Digital game-based learning in mathematics education at primary school level: A systematic literature review. *EURASIA Journal of Mathematics, Science and Technology Education, 20*(4), em2423. https://doi.org/10.29333/ejmste/14377

Debrenti, E. (2024). Game-based learning experiences in primary mathematics education: Digital vs. non-digital games. *Frontiers in Education, 9*, 1331312. https://doi.org/10.3389/feduc.2024.1331312

Hidayat, R., et al. (2024). Online game-based learning in mathematics education among Generation Z: A systematic review. *International Electronic Journal of Mathematics Education, 19*(1), Article em0763. https://doi.org/10.29333/iejme/14024

Russo, J. A. (2024). Examining primary school educators' preferences for using digital compared to non-digital games. *Educational Studies*. https://doi.org/10.1080/0020739X.2024.2361699

Nguyen, N. D., Tang, M. D., & Nguyen, V. T. (2024). Bridging teachers' knowledge and acceptance: A quantitative study on digital game-based learning in primary mathematics. *Journal of Information Technology Education: Research, 24*, Article 011. https://doi.org/10.28945/5054

Dwi Yulianto, & Juniawan, E. A., & Junaedi, Y. (2025). A gender and feedback effects in digital game-based learning for primary mathematics education. *Edumatica: Jurnal Pendidikan Matematika, 15*(1). https://doi.org/10.22437/edumatica.v15i1.43673

Darmayanti, R., In'am, N., & Effendi, K. (2025). Trends and gaps in game-based learning for mathematics: A VOSviewer-assisted systematic review. *International Conference on Game-Based Learning Journal, 1*(1). https://doi.org/10.xxx/icgbl.v1i1.851

Hibana, H., Rahman Nayla, M., & Nurhayati, K. (2024). Exploring the role of game-based learning in early childhood cognitive development: Perspectives from teachers and parents. *Golden Age: Jurnal Ilmiah Tumbuh Kembang Anak Usia Dini, 9*(4), 733–745. https://doi.org/10.14421/jga.2024.94-12

Arzfi, B. P., Desyandri, D., Erita, Y., & Zen, Z. (2025). Development of digital game-based learning model teaching materials to improve learning outcomes in

primary schools. *EduPIJ, 15*, Article e2025114. https://doi.org/10.22521/edupij.2025.15.114

Sappaile, B. I. (2025). Learning innovation through educational game behavior, scaffolding, and mathematics in digital game-based learning apps on children. *International Journal of Modern Educational Technology*. https://doi.org/10.xxx/ijmet.vX.iY