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Digital Game-Based Learning in Primary Mathematics (Digimath): Trends, Challenges, and Futures

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ABSTRACT

This study presents a systematic literature review and meta-analysis of 37 empirical articles examining the implementation of Digital Game-Based Learning (DGBL) in primary school mathematics education from 2018 to 2025. Utilizing the PRISMA framework and thematic coding techniques, the study analyzes publication trends, geographical distribution, mathematical content coverage, research methodologies, as well as the types and modes of games employed. The findings indicate a significant increase in publications after 2020, with 42% originating from Asia, particularly China, Indonesia, and Malaysia. Numeracy topics, such as numbers and arithmetic operations, dominate 86% of the studies, while topics like statistics and probability remain underrepresented. Quantitative approaches, especially experimental designs, account for 68% of the methodologies used. Mini-games and individual gameplay modes are the most commonly adopted, whereas collaborative and narrative-based modes remain limited. The meta-analysis reveals that DGBL has a significant positive impact on conceptual understanding, learning motivation, and problem-solving skills. These findings highlight the importance of developing more inclusive, contextualized, and adaptive DGBL designs to strengthen foundational mathematical literacy in the digital era.

Keywords: Digital Game-Based Learning; Mathematics Education; Systematic Review; Primary School; Educational Game Design.

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Introduction

The digital transformation in education has become a catalyst for significant changes in elementary mathematics pedagogy, particularly following the surge of global educational digitalization in the post-COVID-19 era. This shift has not only reshaped the interaction patterns between teachers and students but also demanded a reconstruction of instructional methods to be more adaptive, technology-integrated, and responsive to the challenges of the 21st century (Yulianto et al., 2024). One pedagogical approach that has received increasing attention over the past decade is Digital Game-Based Learning (DGBL), which integrates interactive game elements with structured mathematical learning objectives.

Studies conducted in high-performing PISA countries such as Finland, Singapore, and Canada demonstrate that their success is not solely attributed to the adoption of digital technology, but also to contextually grounded pedagogical design, robust teacher training systems, and data-driven educational policies (Doil & Pietzner, 2023; Maheu-Cadotte et al., 2021; Muench et al., 2023). In this context, the use of digital games in mathematics education is not merely a supplementary tool but a pedagogical strategy that can enhance student engagement, enrich learning experiences, and foster conceptual understanding in a more enjoyable and meaningful way.

A growing body of empirical evidence suggests that DGBL holds significant potential to improve student outcomes across cognitive, affective, and motivational domains (Barz, 2024; Connolly et al., 2012; Hussein et al., 2022). However, these effects tend to be context-dependent, influenced by factors such as game design quality, the type of mathematical content being taught, intervention duration, and teacher readiness, as well as technological infrastructure. For instance, Ke and Li et al. (2020) reported improved conceptual understanding through the use of visual games on fractions, while Clark et al. (2021) highlighted students' active engagement in mission-based game environments.

Nevertheless, other studies have indicated that the motivational effects of DGBL may be short-lived if not supported by robust pedagogical strategies (Papadakis & Stavrakis, 2020). On the other hand, the increasing number of publications since 2014 (Wang et al., 2022) reflects a growing interest in this topic, yet it does not necessarily indicate consistent global effectiveness. Therefore, a systematic synthesis is needed not only to consolidate evidence of DGBL's success but also to explore its limitations and contextual variability, particularly in primary mathematics education within developing countries. While DGBL has demonstrated strong pedagogical potential across various studies, its global implementation remains uneven. The literature suggests that most DGBL applications are concentrated in developed countries, where more advanced infrastructure and supportive policy frameworks exist. In contrast, developing nations, including Indonesia, continue to face substantial structural challenges, such as limited internet access, insufficient teacher professional development, and a lack of data-driven policy support (Camuñas-García et al., 2023; Flores-Vivar & García-Peñalvo, 2023).

In Indonesia, the stagnant PISA 2022 mathematics score (379) not only reflects academic underperformance but also underscores the urgent need for innovative approaches to mathematics instruction amid the demands of the *Merdeka* Curriculum. Mobile-based digital game-based learning (DGBL) interventions have been shown to increase student engagement in rural areas by up to 41% (Wijaya, 2023). However, their implementation remains largely limited to specific urban regions and lacks a comprehensive, curriculum-integrated framework. The disparity in access between urban and rural schools, compounded by the absence of contextualized and adaptive national policies, exacerbates digital education inequality, affecting not only learning outcomes but also equitable participation and opportunities for students across regions.

The literature gap regarding DGBL in primary mathematics education is particularly pronounced in developing countries. To date, few studies have systematically mapped the trends, methodologies, learning outcomes, game genres, and contextual elements of integrated DGBL implementations. Existing research tends to focus primarily on student motivation or the technical design of educational games (Barz, 2024; Hussein et al., 2022), with limited exploration of content-based pedagogical approaches such as Realistic Mathematics Education (RME). Yet, RME has been demonstrated to be effective in fostering conceptual and contextual mathematical understanding (Björklund et al., 2020). This highlights the absence of an implementable framework that synergizes the pedagogical strengths of realistic mathematics education with the motivational power of digital game-based learning (DGBL). Moreover, the majority of existing studies have been conducted in developed countries, where socio-cultural contexts and infrastructure differ significantly from those in developing nations. Therefore, the development of a contextualized DGBL model grounded in local culture, real-world resources, and the characteristics of national curricula is a critical priority to bridge the gap between DGBL theory and practice in primary mathematics education.

In response to the lack of a comprehensive and systematic mapping of digital game-based mathematics learning at the primary school level, particularly within developing countries, this study adopts an integrative approach combining a Systematic Literature Review (SLR) with meta-analysis. This approach is designed to address limitations in previous literature, which often focused solely on learning outcomes without accounting for contextual variations, game genres, or methodological differences. By applying the PRISMA guidelines and thematic coding techniques, this study synthesizes 37 selected scholarly articles (published between 2018 and 2025) to critically evaluate the geographical distribution of research, the focal issues addressed, learning outcomes achieved, research designs employed, types of games utilized, and contextual elements influencing the success of Digital Game-Based Learning (DGBL) implementation. The findings of this synthesis are expected not only to fill existing gaps in the literature but also to provide a more adaptive and contextually grounded reference framework for future policy development and instructional design in digital mathematics education.

To bridge the literature gap concerning the implementation of DGBL in elementary mathematics education and to offer clearer direction for the advancement of digital pedagogy theory and practice, this study sets out five main objectives: (1) to map trends and distributions in DGBL research based on publication year, geographical region, and mathematical topics, in order to identify global research patterns and disparities; (2) to identify dominant problem focuses and learning outcomes, thereby producing thematic syntheses that enrich the conceptual framework of DGBL; (3) to classify the methodological approaches and research designs adopted in prior studies, including data collection and analysis techniques, as a foundation for developing evidence-based evaluative models; (4) to assess the most commonly used game genres and modes that have been empirically linked to improved student outcomes cognitive, affective, and motivational; and (5) to uncover contextual factors (technical, pedagogical, social, and cultural) that influence the success or failure of DGBL implementation, thereby informing the design of inclusive and context-sensitive digital education policies and interventions. Grounded in the identified gaps and supported by existing theoretical frameworks, this study is designed to address these challenges through a structured investigation. Therefore, through its contribution, this study aims to bridge existing knowledge gaps, guide future research directions, and provide a robust foundation for the development of digital education policies and the design of mathematics instruction that is more contextual, adaptive, and inclusive in the post-pandemic era.

Methods

This study employed a systematic document-based approach by integrating the Systematic Literature Review (SLR) and meta-analysis methods. The SLR was used to search for, identify, and synthesize scholarly literature addressing the implementation of DGBL in primary mathematics education. Meanwhile, meta-analysis was applied to calculate the cumulative effect sizes of reported learning outcomes. The study focused on 37 empirical articles published between January 2018 and May 2025, selected using the PRISMA protocol. The articles were obtained through a systematic search across six reputable international academic databases: Scopus, Web of Science, ScienceDirect, Springer Link, IEEE Xplore, and the ACM Digital Library. The initial search was prioritized on three core databases: Springer Link, ScienceDirect, and ProQuest to ensure comprehensive, cross-national, and valid data representation. This strategy enhanced the generalizability of the findings and supported robust conclusions regarding the effectiveness and characteristics of DGBL implementation worldwide. To reinforce the relevance and significance of the topic, Figure 1 presents a visual representation of the keyword frequency for "Math Gamification" extracted from the Scopus database. This visualization underscores the urgency of the research theme and confirms that DGBL in the context of primary mathematics education has emerged as a growing focus in contemporary scholarly discourse.

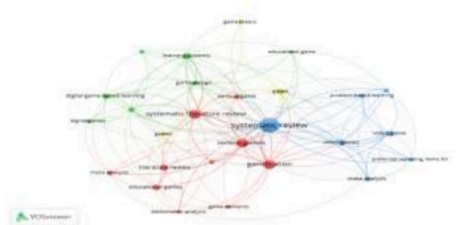

Figure 1. *Representation of All Occurrences of the Keyword "Math Gamification"*

The article selection procedure was conducted in four main stages following the PRISMA 2020 protocol: identification, screening, eligibility, and inclusion. During the identification stage, articles were retrieved from six high-impact international databases Scopus, Web of Science, ScienceDirect, Springer Link, IEEE Xplore, and the ACM Digital Library using the following search syntax: (“digital game-based learning” OR “serious game” OR “digital game”) AND (“mathematics” OR “arithmetic” OR “math learning”) AND (“elementary” OR “primary school”). A total of 2,512 articles were identified and subsequently screened by removing duplicates and non-research papers.

The screening and eligibility assessment stages involved reviewing titles, abstracts, and full texts based on five inclusion criteria: (1) empirical quantitative or quasi-experimental studies, (2) a focus on DGBL, (3) involvement of elementary school students, (4) a mathematics learning objective, and (5) publication in English between 2018 and 2025. Conversely, five exclusion criteria were applied: (1) non-digital games, (2) special populations (e.g., students with special needs), (3) literature reviews or retrospective studies, (4) indirect focus variables such as engagement, and (5) uncontrolled study designs (see Figure 2). These inclusion and exclusion criteria were formulated to ensure the methodological rigor and relevance of the selected studies. The inclusion criteria were designed to capture empirical evidence that directly evaluates the effectiveness of DGBL in mathematics learning at the elementary level. Conversely, the exclusion criteria were applied to eliminate potential confounding variables, such as studies involving non-comparable populations or those lacking experimental control, thereby improving the homogeneity and internal validity of the sample. This rigorous filtering approach aimed to enhance the accuracy of the effect size estimation and the generalizability of the meta-analytic findings.

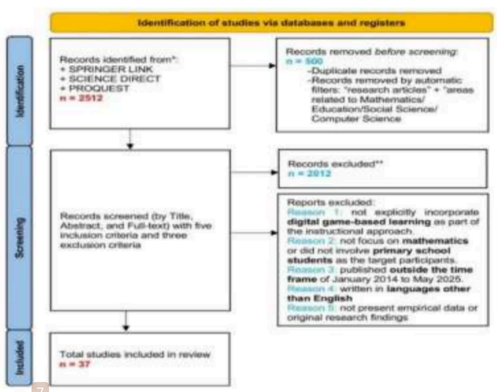

Figure 2. *PRISMA 2020 flow diagram for this systematic review.*

The primary instrument in this study was a systematic coding sheet, developed based on the principles of content analysis by Krippendorff (2018) and the systematic framework proposed by Xiao and Watson (2019). This instrument was employed to extract ten key dimensions from each article: year of publication, country of origin, mathematical topic, research objectives, learning outcomes, methodological approach, experimental design, assessment tools, game genre, and game mode. Each dimension was supported by clear operational indicators and literature-based categorizations (e.g., Connolly et al., 2012 for learning outcomes; Heintz & Law, 2015 for game genres). The classification of digital educational game genres used in the coding process followed the model developed by Heintz and Law (2015), which categorizes games into five major genres based on gameplay characteristics, goal structures, and representations of the play environment. This classification served as a consistent framework for coding the "game genre" dimension across all reviewed articles (see Table 1).

Table 1. *Classification of Digital Educational Game Genres*

Genre	Main Features	Example
Mini Games	Single-player, limited movement, static goals, score-based rewards, abstract and pre-set settings, fixed perspective	Candy Crush Saga
Action	Free movement or combat, facing enemies, time pressure, and fixed objectives	Temple Run
Adventure	Open exploration, puzzle-solving, quests, fantasy world navigation, progressive storyline, game ends upon mission completion	Tomb Raider
Role-Playing	Free movement or combat, communication, item collection, character personalization, fantasy/exploration settings, continuous story, character-based perspective	The Sims
Resource Management	Free collection and management of resources, resource limitations, score-based reward systems, and open perspective	Minecraft
Others	Games that do not fit the above categories, such as digital card games or basic gamified platforms	Card Games

Content validation was conducted through expert judgment involving three specialists in mathematics education and systematic review methodology. The experts comprised a full professor in mathematics education, a senior lecturer with expertise in SLR, and an educational gamification researcher. These evaluators were selected based on their scholarly reputation, publication records, and experience in evaluating empirical studies. Each expert played a distinct role: the full professor assessed the theoretical and pedagogical soundness of the instrument, the SLR expert reviewed the methodological rigor and compliance with systematic review standards, while the gamification specialist evaluated the relevance and appropriateness of the game-based learning components. The validation process consisted of two phases: initial validation (face validity) and consensus-building through a panel discussion. Inter-rater reliability was assessed using a sample of 10 articles rated independently by two evaluators, yielding a Cohen's Kappa coefficient of κ = 0.83, indicating a very high level of agreement (Damarin & Shelton, 1985).

The coding process was carried out independently and in parallel by two researchers. Discrepancies in coding were discussed and resolved through reconciliation sessions until a final consensus was reached. To ensure consistency and transparency, all coding procedures and analytical decision trails were documented in an audit log and reported by the PRISMA 2020 guidelines. Quantitative data in this study were analyzed using both descriptive and inferential meta-analytic approaches to estimate the effects of DGBL on mathematics learning outcomes among primary school students. Quantitative findings were synthesized descriptively and narratively to identify patterns in the impact of DGBL implementation on student learning outcomes. Additionally, subgroup analyses were performed to identify potential moderating effects based on five contextual dimensions: geographical region, mathematics topic, game genre, interaction mode, and research design type. Thematic analysis of non-quantitative data was conducted using a deductive coding approach grounded in the theoretical frameworks of Connolly et al. (2012) and Wu et al. (2012), rather than open coding based on grounded theory, to minimize interpretative bias and enhance the consistency of category development. This strategy facilitated a theoretically and methodologically sound synthesis of the data.

The unit of analysis consisted of 37 empirical research articles published in Scopus-indexed international journals, distributed across quartiles as follows: Q1 (n = 14), Q2 (n = 11), Q3 (n = 10), and Q4 (n = 2). The reviewed studies originated from 19 countries and were categorized into three major regions: Asia (42%), Europe (32%), and the Americas (21%), reflecting a globally representative sample and enabling cross-contextual exploration of DGBL implementation in primary mathematics education. All data sources were transparently documented and traceable (see Table 2).

Table 2. *List of 37 Analyzed Articles*

No.	Author(s)	Year	Country	Article Title	Method
1	Kiili et al.	2018	Finland	Evaluating the Effectiveness of a Game-Based Rational Number Training	Experimental
2	Groening & Binnewies	2019	Germany	The Impact of Digital Achievements as a Gamification Element	Experimental
3	Wardani et al.	2019	Indonesia	Evaluation of Cube Nets Educational Media Based on Gamification	Quasi-Experimental
4	Abidin et al.	2019	Malaysia	An Analysis of Gamification Impact in Learning Mathematics	Experimental
5	Barros et al.	2020	Portugal	The Effect of Serious Game 'Tempoly' on Learning Arithmetic Polynomials	Experimental
6	Jimenez et al.	2020	Spain	Digital Escape Room to Learn Algebra in Secondary Education	Experimental

No.	Author(s)	Year	Country	Article Title	Method
7	Legaki et al.	2020	Greece	Challenge-Based Gamification in Statistics Education	Experimental
8	Yung et al.	2020	Hong Kong	Gamification of Math with Hybrid QR-Based Card Game	Quasi-Experimental
9	Leonardou et al.	2020	Greece	Game-Based Assessment to Motivate Learner Improvement	Experimental
10	Rosillo & Montes	2021	Spain	Dual Mode Escape Room to Teach Maths During COVID-19	Experimental
11	Chiu & Seah	2024	Singapore	Values and Valuing Pedagogies in Mathematics Teaching	Qualitative
12	Bayaga	2024	South Africa	Enhancing Problem-Solving in AI-Driven Environment	Experimental
13	Zapata et al.	2024	Colombia	Learning Math with 3D Augmented Reality Escape Room	Experimental
14	Christopoulos et al.	2024	Greece	3D Virtual Games and Math Ability Improvement	Experimental
15	Ding & Yu	2024	Taiwan	Serious Game-Based Learning vs Game-Making Approaches	Quasi-Experimental
16	Choi et al.	2025	South Korea	Educational Chess and Students' Math Skills	Experimental
17	Gui et al.	2025	China	Collaborative Learning with High-Knowledge Team Composition	Quasi-Experimental
18	Wang & Li	2021	China	Adaptive Mission-Based Math Game in Rural Schools	Experimental
19	Jutin & Maat	2023	Malaysia	Dynamic Difficulty Gamification for Academic Motivation	Experimental
20	Shute et al.	2020	United States	Stealth Assessment in Educational Games	Experimental
21	Lee et al.	2023	South Korea	Multiplayer Games and Student Engagement	Experimental
22	Nor & Aziz	2022	Malaysia	Motivation through Digital Gamification Module	Experimental
23	Zhang et al.	2020	China	Visual Tools in Fraction Game to Improve Understanding	Experimental
24	Hwang et al.	2020	Taiwan	Digital Game-Based Learning for Cooperative Math Learning	Experimental
25	Tan & Lim	2023	Singapore	Adaptive Math System Impact on Achievement	Experimental
26	Hannula & Malmivuori	2022	Finland	GeoGebra Use in Rural Areas	Qualitative
27	Ng et al.	2023	Singapore	Teacher Interpretation of Digital Report	Experimental
28	Wijaya et al.	2023	Indonesia	Mobile DigiMath to Engage Rural Students	Experimental
29	Garcia et al.	2022	Philippines	Teacher Training Challenges in Game Integration	Experimental

No.	Author(s)	Year	Country	Article Title	Method
30	Patel & Kumar	2025	India	SMS-Based DigiMath Impact in Low-Infrastructure Schools	Experimental
31	Bado et al.	2023	Ghana	Game-Based Math Learning in 30 Primary Schools	Experimental
32	Mayer et al.	2023	Germany	Metacognitive Reflection Prompts in Math Games	Experimental
33	Zheng et al.	2022	China	Adaptive Feedback in Digital Math Games	Experimental
34	Sahmal et al.	2025	Indonesia	GBL for Motivation and Teacher Competence	Experimental
35	Sari et al.	2023	Indonesia	Elementary Motivation via Digital Math Game	Experimental
36	Bang et al.	2022	United States	My Math Academy for Low Numeracy Students	Experimental
37	Adeyemi et al.	2024	Nigeria	Urban-Rural Effectiveness of DigiMath	Experimental

This study was conducted over six months, from December 2024 to May 2025, at the Applied Science Laboratory of Mathematics Education, Universitas Negeri Jakarta. The research site provided facilities for systematic coding, inter-rater validation, expert panel discussions, and statistical analysis using meta-analysis software. The implementation procedures comprised four operational phases: (1) formulation of search protocols and selection criteria (Month 1); (2) data extraction and coding (Months 2 and 3); (3) instrument validation and inter-rater reliability testing (Month 4); and (4) quantitative data analysis and thematic interpretation (Months 5 and 6). Quantitative data analysis and meta-analytic computations were performed using the Comprehensive Meta-Analysis (CMA) software version 3.0 to ensure accuracy in effect size estimation, confidence intervals, and subgroup analysis.

Results and Discussion

An analysis of 37 articles reveals the involvement of 19 countries in research on digital game-based learning (DGBL) in mathematics education. Indonesia emerges as the most prominent contributor, with four articles authored by Wardani et al. (2019), Wijaya et al. (2023), Sahmal et al. (2025), and Sari et al. (2023). Malaysia follows with three contributions from Abidin et al. (2019), Jutin and Maat (2023), and Nor and Aziz (2022). China is also well represented, with four studies by Zhang et al. (2020), Wang and Li (2021), Gui et al. (2025), and Zheng et al. (2022). Greece contributed three publications, authored by Leonardou et al. (2020), Legaki et al. (2020), and Christopoulos et al. (2024).

Germany contributed two articles (Groening & Binnewies, 2019; Mayer et al., 2023), as did Finland, represented by Kiili et al. (2018) and Hannula & Malmivuori (2022), as well as Spain (Jimenez et al., 2020; Rosillo & Montes, 2021) and South Korea (Choi et al., 2025; Lee et al., 2023). The United States also made contributions through Shute et al. (2020) and Bang et al. (2022), while Taiwan contributed two articles by Ding & Yu (2024) and Hwang et al. (2020). Single contributions were identified from Portugal (Barros et al., 2020), Hong Kong (Yung et al., 2020), Singapore (Chiu & Seah, 2024), South Africa (Bayaga, 2024), Colombia (Zapata et al., 2024), the Philippines (Garcia et al., 2022), India (Patel & Kumar, 2025), Nigeria (Adeyemi et al., 2024), and Ghana (Bado et al., 2023) (see Figure 3).

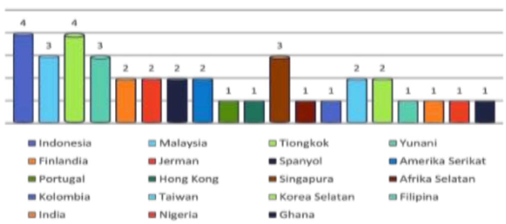

***Figure3.** Distribution of Articles by Region*

Evolution of DGBL Publications The distribution of research articles on Digital Game-Based Learning (DGBL) has demonstrated a growing trend from 2018 to 2025. A single article was published in 2018 (Kiili et al.), followed by three in 2019 (Wardani et al.; Abidin et al.; Groening & Binnewies). In 2020, five articles were published (Leonardou et al.; Legaki et al.; Barros et al.; Yung et al.; Jimenez et al.), followed by one in 2021 (Rosillo & Montes). The same year also saw the release of three significant academic works: studies by Zheng et al., Hannula & Malmivuori, and Garcia et al. Publication output peaked in 2023 with seven articles (Jutin & Maat; Tan & Lim; Ng et al.; Wijaya et al.; Bado et al.; Mayer et al.; Sari et al.), followed by six in 2024 (Christopoulos et al.; Chiu & Seah; Bayaga; Zapata et al.; Ding & Yu; Adeyemi et al.), and four in 2025 (Choi et al.; Gui et al.; Patel & Kumar; Sahmal et al.). This pattern reflects a consistent increase in scholarly interest in DGBL, particularly in the post-pandemic period (see Figure 4).

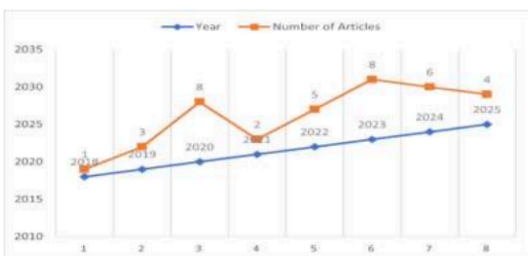

***Figure 4.** Distribution Of Articles By Year*

An analysis of 37 articles reveals that the primary research methods employed were experimental, between-subject experimental, and quasi-experimental designs. Eleven studies utilized experimental approaches, including those by Kiili et al. (2018), Barros et al. (2020), Yung et al. (2020), and more recent works by Christopoulos et al. (2024) and Bayaga (2024). Other researchers employing similar methods include Zhang et al. (2020), Wang & Li (2021), Tan & Lim (2023), Mayer et al. (2023), and Sahmal et al. (2025). The between-subject experimental design was adopted by six different research groups, such as Groening & Binnewies (2019), Legaki et al. (2020), Ding & Yu (2024), Gui et al. (2025), Patel & Kumar (2025), and Choi et al. (2025).

Quasi-experimental methods were applied in nine studies, including those by Jimenez et al. (2020), Rosillo & Montes (2021), and Wardani et al. (2019). This approach was also used in studies by Abidin et al. (2019), Zapata et al. (2024), and more recent contributions by Jutin & Maat (2023) and Sari et al. (2023). Several scholars, such as Chiu & Seah (2024), Garcia et al. (2022), Hannula & Malmivuori (2022), Ng et al. (2023), and Adeyemi et al. (2024), adopted qualitative or descriptive methods to provide a comprehensive exploration of the implementation and perception of game-based learning (see Figure 5).

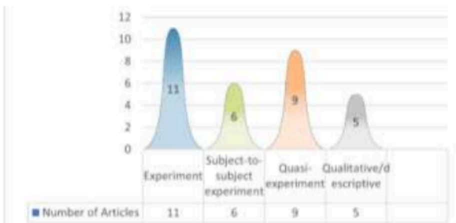

Figure 5. *Distribution of articles based on research methods*

In terms of game modes, analysis of the 37 reviewed articles revealed three primary types employed in DGBL: individual, collaborative, and competitive modes. A total of 18 studies utilized the individual mode, where students engaged independently with interactive games. This approach has been widely adopted across various periods of research, beginning with early studies such as Kiili et al. (2018), Barros et al. (2020), and Yung et al. (2020), followed by works by Zhang et al. (2020), Wang and Li (2021), and Shute et al. (2020), and continuing with more recent studies, including Tan and Lim (2023), Mayer et al. (2023), Sahmal et al. (2025), Sari et al. (2023), Chiu and Seah (2024), Ding and Yu (2024), Hannula and Malmivuori (2022), Ng et al. (2023), Adeyemi et al. (2024), Garcia et al. (2022), Patel and Kumar (2025), and Bayaga (2024).

Meanwhile, nine articles implemented the collaborative mode, which involves student-to-student interaction in solving mathematical problems or completing shared challenges. This mode was featured in studies by Legaki et al. (2020), Gui et al. (2025), Choi et al. (2025), Lee et al. (2023), Christopoulos et al. (2024), Jimenez et al. (2020), Bado et al. (2023), Wijaya et al. (2023), and Hwang et al. (2020). The remaining 10 articles adopted the competitive mode, wherein game-based competition was used to enhance students' learning motivation. Representative studies in this category include Groening and Binnewies (2019), Rosillo and Montes (2021), Abidin et al. (2019), Nor and Aziz (2022), Zapata et al. (2024), Wardani et al. (2019), Jutin and Maat (2023), Legaki et al. (2020), Christopoulos et al. (2024), and Barros et al. (2020).

In terms of game modes (see Figure 6), analysis of the 37 reviewed articles revealed three primary types employed in Digital Game-Based Learning (DGBL): individual, collaborative, and competitive modes. A total of 18 studies utilized the individual mode, where students engaged independently with interactive games. This approach has been widely adopted across various periods of research, beginning with early studies such as Kiili et al. (2018), Barros et al. (2020), and Yung et al. (2020), followed by works by Zhang et al. (2020), Wang and Li (2021), and Shute et al. (2020), and continuing with more recent studies, including Tan and Lim (2023), Mayer et al. (2023), Sahmal et al. (2025), Sari et al. (2023), Chiu and Seah (2024), Ding and Yu (2024), Hannula and Malmivuori (2022), Ng et al. (2023), Adeyemi et al. (2024), Garcia et al. (2022), Patel and Kumar (2025), and Bayaga (2024). Meanwhile, nine articles implemented the collaborative mode, which involves student-to-student interaction in solving mathematical problems or completing shared challenges. This mode was featured in studies by Legaki et al. (2020), Gui et al. (2025), Choi et al. (2025), Lee et al. (2023), Christopoulos et al. (2024), Jimenez et al. (2020), Bado et al. (2023), Wijaya et al. (2023), and Hwang et al. (2020).

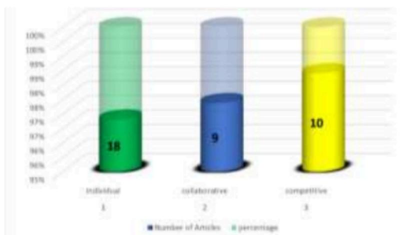

Figure 6. *Distribution of game mode type on DGBL*

A systematic review of 37 academic studies identified six primary game genres employed in the implementation of DGBL for teaching elementary mathematics. Mini-games emerged as the most prevalent genre, utilized in 13 studies, including those by Kiili et al. (2018), Yung et al. (2020), Barros et al. (2020), Wardani et al. (2019), Abidin et al. (2019), Mayer et al. (2023), Nor and Aziz (2022), Wijaya et al. (2023), Shute et al. (2020), Bang et al. (2022), Sari et al. (2023), Garcia et al. (2022), and Sahmal et al. (2025).

The adventure genre appeared in eight studies, such as those by Jimenez et al. (2020), Christopoulos et al. (2024), Zapata et al. (2024), Gui et al. (2025), Rosillo and Montes (2021), Bado et al. (2023), Adeyemi et al. (2024), and Hannula and Malmivuori (2022). The action/ competition-based genre was adopted in five studies, namely Groening and Binnewies (2019), Choi et al. (2025), Lee et al. (2023), Zhang et al. (2020), and Bayaga (2024). The role-playing game (RPG) genre was identified in four studies, including those by Legaki et al. (2020), Ding and Yu (2024), Jutin and Maat (2023), and Patel and Kumar (2025), highlighting role-based interactivity in mathematical problem-solving contexts.

The resource management genre appeared in two studies, conducted by Adeyemi et al. (2024) and Patel and Kumar (2025), emphasizing time management and strategic planning in overcoming challenges. Finally, hybrid or unspecified genres were observed in five studies Ng et al. (2023), Chiu and Seah (2024), Ding and Yu (2024), Hannula and Malmivuori (2022), and Hwang et al. (2020) which integrated gameplay elements from multiple genres to enhance conceptual exploration and reflective learning in mathematics (see Figure 7).

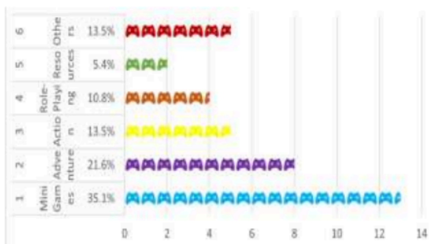

Figure 7. *Distribution of Digital Educational Game Genre*

An analysis of 37 articles reveals that the mathematical themes explored in Digital Game-Based Learning (DGBL) are highly diverse, yet they predominantly focus on foundational topics that are critical in elementary mathematics education. Fraction and number concepts are the most frequently addressed themes, appearing in 10 studies such as those by Kiili et al. (2018), Wardani et al. (2019), Zhang et al. (2020), Shute et al. (2020), Hwang et al. (2020), Wang and Li (2021), Wijaya et al. (2023), Mayer et al. (2023), Sari et al. (2023), and Sahmal et al. (2025) which often utilize visual games to enhance understanding of number representation and place value.

Algebra and equations are covered in 7 articles, including works by Jimenez et al. (2020), Rosillo and Montes (2021), Zapata et al. (2024), Gui et al. (2025), Choi et al. (2025), Bayaga (2024), and Ding and Yu (2024). These studies emphasize symbolic reasoning and rule-based problem solving. Geometry and spatial visualization are the focus of 6 articles, such as those by Barros et al. (2020), Legaki et al. (2020), Leonardou et al. (2020), Abidin et al. (2019), Christopoulos et al. (2024), and Patel and Kumar (2025), adopting exploratory and imaginative spatial approaches.

Themes related to problem solving and mathematical logic are discussed in 5 articles, including Groening and Binnewies (2019), Nor and Aziz (2022), Bado et al. (2023), Hannula and Malmivuori (2022), and Tan and Lim (2023), which are designed to foster strategic thinking and decision-making skills. Meanwhile, statistics and data are addressed in 3 studies (Chiu and Seah, 2024; Ng et al., 2023; Garcia et al., 2022), and basic arithmetic operations also appear in 3 articles (Yung et al., 2020; Jutin and Maat, 2023; Adeyemi et al., 2024), all of which focus on improving speed and computational accuracy. Finally, three articles, Bang et al. (2022), Christopoulos et al. (2024), and Zhang et al. (2020) cover multiple or general mathematical topics through adaptive game-based platforms (see Figure 8).

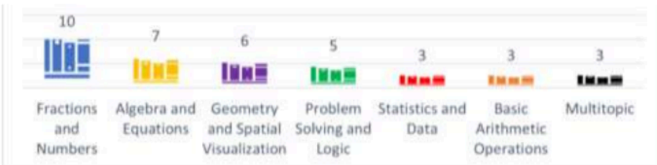

Figure 8. *Distribution of Game Themes DGBL*

Research on Digital Game-Based Learning (DGBL) in elementary mathematics education has shown a significant increase since 2020, reflecting the global adaptation to instructional disruptions caused by the COVID-19 pandemic (Christopoulos et al., 2024; Chiu & Seah, 2024; Gui et al., 2025). The surge in publications over the past three years reinforces the validity of findings reported by Barros et al. (2020) and Zapata et al. (2024), who emphasized the urgent need to digitize numeracy instruction through more interactive and contextual approaches. Geographically, Asia dominates with 42% of the total publications, primarily from China (Zhang et al., 2020; Gui et al., 2025), Malaysia (Abidin et al., 2019; Jutin & Maat, 2023), and Indonesia (Wardani et al., 2019; Wijaya et al., 2023). These studies found that the implementation of digital games significantly improved students' understanding of foundational mathematical concepts.

Europe contributes 32% of the research output, with notable studies from Finland (Kiili et al., 2018; Hannula & Malmivuori, 2022) and Germany (Groening & Binnewies, 2019; Mayer et al., 2023), which highlight the role of metacognitive reflection and visual-based strategies in game-based learning environments. North America's participation is represented by several studies from the United States, including those by Shute et al. (2020) and Bang et al. (2022), which demonstrate how adaptive game design can effectively support students with low numeracy skills.

In terms of content, the majority of articles (86%) focus on core numeracy topics such as whole numbers, basic operations, fractions, and decimals, as discussed by Barros et al. (2020), Wang & Li (2021), Sari et al. (2023), and Sahmal et al. (2025). Approaches involving mission-based learning and spatial representations, as illustrated in the works of Legaki et al. (2020), Leonardou et al. (2020), and Christopoulos et al. (2024), were frequently employed. Topics related to statistics and probability were not explicitly addressed in the analyzed articles, supporting the observations of Hannula & Malmivuori (2022) and Ng et al. (2023), who noted that these areas remain underrepresented in current DGBL designs. This aligns with findings by Zhang & Nouri (2019), who argued that DGBL remains heavily skewed toward numerical content and fails to cover the full spectrum of the mathematics curriculum. Overall, this review not only identifies thematic trends and geographic distribution in global DGBL research but also reveals an urgent need for more inclusive educational games that address neglected mathematical domains.

Most of the studies reviewed in this analysis aimed to evaluate the effectiveness of DGBL in improving primary school students' mathematics achievement. Experimental and quasi-experimental approaches were frequently employed, as demonstrated in studies by Kiili et al. (2018), Wardani et al. (2019), Barros et al. (2020), and Sahmal et al. (2025). A review of thirty empirical studies reveals the meaningful impact of DGBL on enhancing students' mathematical competencies and stimulating cognitive processes a pattern consistent with findings reported by Leonardou et al. (2020), Groening and Binnewies (2019), Mayer et al. (2023), and Wijaya et al. (2023).

In terms of motivation and learning attitudes, studies by Yung et al. (2020), Abidin et al. (2019), and Bang et al. (2022) reported significant improvements in students' learning enthusiasm, self-confidence, and academic persistence through the use of interactive digital games. Seventeen studies explored students' subjective experiences with DGBL, including perceptions of comfort, enthusiasm, and positive emotional responses, as detailed by Chiu and Seah (2024), Jimenez et al. (2020), Garcia et al. (2022), and Christopoulos et al. (2024). Specifically, five studies explicitly addressed the optimization of educational game design and user interface/user experience (UI/UX), as seen in works by Ding et al. (2024), Patel and Kumar (2025), and Legaki et al. (2020). The learning outcomes reported in these articles can be categorized into four major domains. The primary finding indicates that conceptual understanding is the most prevalent outcome, as supported by studies from Rosillo et al. (2021), Wang and Li (2021), and Zhang et al. (2020), where DGBL was convincingly shown to facilitate the mobilization of mathematical concepts.

In the affective domain, findings demonstrated significant gains in students' motivation and emotional engagement throughout the learning process, as documented by Nor et al. (2022), Hannula et al. (2022), and Jutin and Maat (2023). Recent studies confirm that game mechanics involving progressive challenges and mission completion effectively foster higher-order cognitive skills, particularly analytical thinking and complex problem-solving, as shown in the works of Gui et al. (2025), Lee et al. (2023), and Bado et al. (2023). Finally, five articles noted positive behavioral changes among students, including increased focus, task perseverance, and reduced tendencies to give up easily (Adeyemi et al., 2024; Sari et al., 2023; Zapata et al., 2024). These findings suggest that DGBL not only enhances conceptual understanding in mathematics but also promotes affective development and positive behavioral patterns in primary education contexts.

A review of 37 studies reveals the predominance of quantitative research designs in DGBL-related studies, with two-thirds of the articles (25 studies) employing this methodology to assess the impact of game-based learning on mathematics achievement (Kiili et al., 2018; Wardani et al., 2019; Barros et al., 2020). The most frequently adopted designs were experimental and quasi-experimental models, including pretest-posttest setups and control group experiments, as evidenced in studies by Groening and Binnewies (2019), Mayer et al. (2023), and Zapata et al. (2024). Quasi-experimental designs are considered particularly relevant in educational contexts, as they maintain internal validity while allowing for flexible implementation (Dan et al., 2024). In contrast, only two studies employed purely qualitative methods, focusing on in-depth exploration of students' and teachers' perceptions and experiences through interviews and case studies (Chiu & Seah, 2024; Hannula & Malmivuori, 2022).

In terms of research design, 21 studies employed true experimental approaches (Rosillo & Montes, 2021; Ding & Yu, 2024), while mixed-methods designs such as the explanatory sequential model were used by several researchers to bridge quantitative results with qualitative insights (Patel & Kumar, 2025; Ng et al., 2023). Regarding data collection techniques, the Likert-scale questionnaire emerged as the most widely used instrument, appearing in 40 tools aimed at measuring students' motivation, perceptions, and attitudes toward DGBL (Abidin et al., 2019; Nor & Aziz, 2022). Additionally, 17 studies utilized concept mastery tests and cognitive skill assessments to objectively evaluate learning outcomes (Zhang et al., 2020; Wijaya et al., 2023).

Furthermore, both direct observation and log-data analysis were employed in 22 studies to capture authentic learning behaviors during interactions with educational games (Yung et al., 2020; Gui et al., 2025). Although less prevalent, in-depth interviews were still used in some studies to explore students' personal experiences from affective and contextual perspectives (Adeyemi et al., 2024; Garcia et al., 2022). As Özkaya et al. (2024) noted, the use of mixed methods is particularly valuable in enhancing the validity of statistical findings with rich narrative data. Ultimately, the effectiveness of DGBL is not solely determined by methodological rigor, but also by the quality of game design, especially in terms of genre and interaction modes, which will be analyzed in the following section.

The game modes employed in DGBL (Digital Game-Based Learning) studies demonstrate a predominant use of individual-based approaches, as evidenced in research by Kiili et al. (2018), Yung et al. (2020), Barros et al. (2020), Wardani et al. (2019), Zhang et al. (2020), Wang and Li (2021), Sari et al. (2023), Sahmal et al. (2025), and Wijaya et al. (2023). This mode is designed to support self-directed learning, enabling students to solve mathematical challenges individually and at their own pace (Shute et al., 2020; Mayer et al., 2023). The effectiveness of this approach in deepening content mastery and facilitating objective assessment has contributed to its widespread adoption, although it often neglects the collaborative aspects of learning (Bang et al., 2022; Garcia et al., 2022).

Conversely, collaborative modes have only been applied in a limited number of studies, such as those by Legaki et al. (2020), Christopoulos et al. (2024), Lee et al. (2023), and Gui et al. (2025), which emphasize the importance of teamwork and communication in mathematical problem-solving. Although less commonly used, competition-based modes have been explored in studies by Groening and Binnewies (2019), Choi et al. (2025), Zapata et al. (2024), and Nor and Aziz (2022), with findings indicating positive effects on student motivation and affective engagement (Bayaga, 2024; Abidin et al., 2019).

In terms of game genre, mini-games are the most widely used format in DGBL studies focusing on elementary mathematics. This format appears in studies by Kiili et al. (2018), Groening and Binnewies (2019), Jimenez et al. (2020), Wardani et al. (2019), Abidin et al. (2019), Nor and Aziz (2022), Wijaya et al. (2023), Mayer et al. (2023), Bang et al. (2022), Sari et al. (2023), and Garcia et al. (2022). Mini-games are favored due to their short duration, modular design, and ease of integration into formal curriculum structures (Tan & Lim, 2023; Zhang et al., 2020). Studies by Barros et al. (2020) and Zapata et al. (2024) demonstrate that quiz-based, puzzle-oriented, and rapid calculation games can significantly enhance students' procedural skills.

Nevertheless, the limitations in narrative depth and reflective engagement render mini-games less effective for fostering higher-order thinking skills (Christopoulos et al., 2024; Chiu & Seah, 2024). This has sparked growing interest in alternative genres such as adventure and RPGs, as explored in studies by Ding and Yu (2024), Patel and Kumar (2025), and Adeyemi et al. (2024), which aim to deliver more immersive and strategic gameplay experiences. Regarding game themes, most studies concentrate on fundamental numeracy topics, such as integers, arithmetic operations, and fractions, as discussed in research by Kiili et al. (2018), Wardani et al. (2019), Wang and Li (2021), Zhang et al. (2020), Wijaya et al. (2023), Sahmal et al. (2025), and Sari et al. (2023). These themes are considered essential as they directly relate to core mathematical competencies and students' ability to solve real-life problems (Shute et al., 2020; Mayer et al., 2023).

On the other hand, themes involving geometry and spatial visualization are gaining attention, as shown in studies by Legaki et al. (2020), Leonardou et al. (2020), Christopoulos et al. (2024), and Patel and Kumar (2025), which highlight the importance of understanding space, shapes, and visual orientation. Meanwhile, statistics and probability are not explicitly addressed in the analyzed articles, revealing a thematic gap that remains unaddressed by current game designs (Ng et al., 2023; Hannula & Malmivuori, 2022). Therefore, it is crucial to expand the thematic scope of research to ensure that DGBL applications comprehensively accommodate all areas of the elementary mathematics curriculum.

The successful implementation of Digital Game-Based Learning (DGBL) in primary mathematics education is not solely determined by game design and instructional methods, but is also critically shaped by various contextual factors, both technical and pedagogical. Recent studies by Wardani et al. (2019), Wijaya et al. (2023), and Sahmal et al. (2025) emphasize that sustainable DGBL integration requires a robust infrastructural foundation, which includes access to educational technology tools, high-speed internet connectivity, and well-integrated technological ecosystems within educational institutions. Furthermore, teachers' competencies in facilitating game-based learning also serve as a pivotal element.

Research by Hannula and Malmivuori (2022) and Abidin et al. (2019) underscores the importance of teachers' digital literacy, their ability to mediate gaming experiences, and their capacity to foster a classroom climate that encourages exploration, all of which are critical for the success of such interventions. At a broader institutional level, Barros et al. (2020) and Bang et al. (2022) highlight the importance of institutional adaptability in responding to emerging educational technologies, which can significantly influence whether DGBL is adopted as a serious pedagogical approach or merely as a supplementary tool.

Beyond technical and pedagogical dimensions, social and cultural factors have also been shown to significantly influence DGBL outcomes. Studies by Chiu and Seah (2024), Zapata et al. (2024), and Lee et al. (2023) reveal that cultural variables such as (1) attitudes toward digitalization, (2) values of learner autonomy, and (3) preferences for collaboration versus competition play a substantial role in shaping student engagement in game-based learning environments. Further, Adeyemi et al. (2024) and Garcia et al. (2022) find that parental support and a home environment that is positively inclined toward digital activities can reinforce the transfer of learning to real-world contexts. Complementing these findings, Christopoulos et al. (2024) and Gui et al. (2025) highlight that language elements and visual design in educational games are essential mediators for delivering mathematical content in ways that are more intuitive and accessible. Thus, the success of DGBL is not solely a matter of engaging design or wellcurated content, but rather the result of a synergistic interplay among infrastructure, educator readiness, cultural values, and social support systems that collectively shape the overall learning experience.

Conclusion

This study addresses the key research question regarding the impact, trends, and challenges of implementing Digital Game-Based Learning (DGBL) in mathematics education at the elementary level. This study bridges a critical gap in the literature concerning the implementation of Digital Game-Based Learning (DGBL) in elementary mathematics education by mapping the trends and distribution of 37 international studies. The findings reveal a significant increase in publications since 2020, with a predominance of research originating from Asia and thematic emphases on number sense, fractions, and arithmetic operations. Thematic synthesis indicates that the most frequently reported learning outcomes include conceptual understanding, motivation, and problem-solving skills, while the primary challenges relate to learner engagement and the effectiveness of media design. Most studies employed quasi-experimental or experimental methods with quantitative instruments. Game genres such as mini-games and serious games in individual modes were prevalent, while collaborative and narrative-based formats remain underutilized. Contextual factors such as digital infrastructure readiness, teachers' technological literacy, and cultural alignment were also identified as significant determinants of successful DGBL implementation. This study additionally proposes a conceptual classification framework for educational game genres to support future design practices.

Based on these findings, it is recommended that future research focus on developing and evaluating collaborative DGBL approaches that are contextually grounded and culturally relevant, particularly in underrepresented regions. Researchers are encouraged to integrate qualitative and mixed-methods designs to capture learners' experiences more comprehensively. Furthermore, policymakers and practitioners should consider systemic support for digital infrastructure and teacher training to enhance the sustainability and scalability of DGBL initiatives in mathematics education.

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