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Dwi Yulianto[1*], Yusup Junaedi[1], Syahrul Anwar[1], Nita Puspitasari[1]

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1st Author full name: Dwi Yulianto Afiliation:Latansa Mashiro University Email: dwiyulianto554@gmail.com Whatsapp/SMS number (optional): 081292928306 Orcid ID: https://orcid.org/0000-0002-1143-2146	3rd Author full name: Syahrul Anwar Afiliation: Latansa Mashiro University Email: anwarsyahrul291@gmail.com Whatsapp/SMS number (optional): 085311847008 Orcid ID: https://orcid.org/0000-0001-9822-0498
2nd Author full name: Yusup Junaedi Afiliation: Latansa Mashiro University Email: yusufjuna4@gmail.com Whatsapp/SMS number (optional): 085215876965 Orcid ID: https://orcid.org/0000-0002-5138-2374	4th Author full name: Nita Puspitasari Afiliation: Latansa Mashiro University Email: nitapuspitasari502@gmail.com Whatsapp/SMS number (optional): 081294732263 Orcid ID: https://orcid.org/0009-0002-0744-3501
You may add more authors here	*You may add more authors here*

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Systematic Review on the Impact of Game-Based Learning on Students' Cognitive and Affective Domains

Dwi Yulianto[1*], Yusup Junaedi[1], Syahrul Anwar[1], Nita Puspitasari[1]

[1]Department of Mathematics Education, Latansa Mashiro University, Indonesia.

ABSTRACT

This study employed a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines to evaluate the impact of Game-Based Learning (GBL) on students' cognitive and affective domains in mathematics education, synthesizing evidence from 17 empirical studies published between 2018 and 2025. The findings consistently indicate that GBL significantly improves cognitive outcomes, including conceptual understanding, problem-solving skills, and critical thinking abilities, particularly when supported by digital tools such as augmented reality, 3D escape rooms, and gamified platforms. In addition, GBL positively influences affective outcomes by increasing student motivation and fostering more favorable attitudes toward mathematics, while also reducing math anxiety. However, assessments of affective domains remain less standardized compared to those of cognitive outcomes. Key contextual factors such as students' prior knowledge, the quality of game design, intervention duration, and teacher preparedness were found to be critical in determining GBL effectiveness. The review highlights the dominance of digital GBL in resource-rich environments, while also recognizing the potential of non-digital adaptations in low-resource contexts. Drawing on diverse international evidence, this review underscores GBL's potential as an innovative pedagogical strategy that effectively integrates cognitive and affective learning. Practical recommendations include culturally responsive game design, comprehensive teacher training, and equitable access to technology to ensure successful GBL implementation across varied educational settings.

KEYWORDS

Game-Based Learning; Mathematics Education; Cognitive Domain; Affective Domain; Systematic Review

CORRESPONDING AUTHOR

Name of the corresponding author ✉ corresponding_author@email.com 🖃 Department, University, City, Country

INTRODUCTION

Mathematics education, both in developed and developing countries like Indonesia, is fundamental in preparing learners for the demands of the 21st century marked by digitalization, automation, and complex problem-solving (Szabo et al., 2020; Yulianto et al., 2024). However, despite its importance, mathematics often triggers anxiety and disengagement, leading to low achievement worldwide, especially in developing regions where PISA and TIMSS scores remain below the OECD average (OECD, 2023; Kelly et al., 2020; IEA, 2020). These challenges call for pedagogical innovation beyond curriculum reform, emphasizing cognitive and affective integration. Effective learning requires student-centered strategies that build reasoning, conceptual fluency, and motivation (Bloom et al., 1956; Kunani et al., 2025). In response, Game-Based Learning (GBL) has gained prominence as an approach that enhances problem-solving, reasoning, and student engagement through

interactive, technology-enhanced platforms such as digital simulations, puzzles, and gamified assessments (Hu et al., 2022; Gundersen & Lampropoulos, 2025).

GBL has gained widespread attention in STEM education for its constructivist approach, real-time feedback, and ability to reduce mathematics anxiety (Moon et al., 2024; Munirah et al., 2020). While promising results are evident in high-income countries, findings from developing regions remain fragmented, complicated by varied game types, digital simulations, board games, and inconsistent research designs and outcome measures (Radkowitsch et al., 2021). Prior studies have largely emphasized cognitive outcomes, with limited focus on affective domains crucial for sustaining motivation and learning success (Varas-Pavez et al., 2025). Moreover, only 15% of GBL research employs standardized tools for affective assessment (Radkowitsch et al., 2021), and few explore its role in shaping emotional engagement or attitudes in mathematics learning (Lee Yan & Mohd Matore, 2023). Addressing these gaps, this review adopts PRISMA 2020 guidelines and thematic synthesis, rarely been applied in prior mathematics GBL reviews to comprehensively map cognitive and affective impacts across diverse contexts.

To address this gap, this study conducts a systematic literature review (SLR) of peer-reviewed articles published between 2018 and 2025, focusing on both cognitive (problem-solving, reasoning, conceptual understanding) and affective (motivation, attitude, engagement) outcomes of GBL in mathematics education dimensions rarely integrated in previous reviews. This dual focus offers theoretical and practical insights for developing evidence-based, emotionally responsive GBL frameworks, which are increasingly critical in the post-pandemic era marked by rapid digital and remote learning expansion (Szabo et al., 2020; OECD, 2023).

The 2018–2025 timeframe captures the acceleration of educational technologies and GBL adoption triggered by COVID-19, underscoring the need for a comprehensive synthesis to guide hybrid and virtual teaching models. Moreover, this review advances prior studies by rigorously applying PRISMA 2020 guidelines and thematic synthesis, ensuring methodological transparency and replicability elements often lacking in earlier GBL-focused SLRs (Radkowitsch et al., 2021). Specifically, this study aims to: (1) assess GBL's impact on students' cognitive development; (2) evaluate its influence on affective domains; (3) identify key GBL implementation themes; and (4) explore contextual factors moderating GBL effectiveness.

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METHODS

Review Type and Objectives

This study employed a systematic literature review (SLR) guided by the PRISMA 2020 protocol (Page et al., 2021), aiming to synthesize empirical evidence on the effects of Digital Game-Based Learning (DGBL) on students' cognitive (conceptual understanding, reasoning, problem-solving, critical and creative thinking) and affective outcomes (motivation, engagement, attitudes) in primary and secondary mathematics education. The review period of 2018–2025 was chosen to capture recent advancements in digital Game-Based Learning (DGBL), especially given the surge in technology adoption during and after the COVID-19 pandemic, which has significantly transformed educational practices globally.

Data Sources and Search Strategy

The literature search was conducted in Scopus, Web of Science (WoS), and ScienceDirect using Boolean operators ("AND", "OR") with the terms: "game-based learning" OR "gamification" AND "mathematics" OR "mathematics education" AND "cognitive domain" OR "affective domain". The search was limited to peer-reviewed English journal articles, published between January 2018 and May 2025, available in full-text Open Access. A pilot search was first carried out to refine keywords and Boolean strings for relevance and retrieval quality. Citation tracking and grey literature were excluded to maintain methodological rigor and reduce publication bias. Figure 1 illustrates the distribution of the term "math gamification" in the Scopus database.

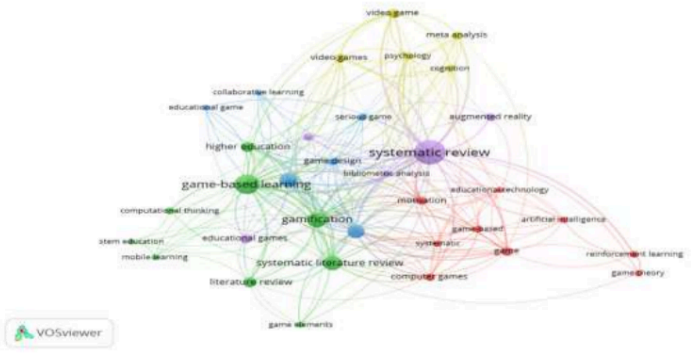

Figure 1. Distribution of the Term "Math Gamification" Based on Scopus Database Retrieval

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Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were established to ensure the relevance and methodological rigor of this systematic review. Included studies were empirical, focused on Digital Game-Based Learning (DGBL) in mathematics education, involved primary or secondary students, measured cognitive and/or affective outcomes using clear indicators, applied experimental or quasi-experimental designs with group comparisons, and were peer-reviewed English journal articles. Excluded studies were those involving non-digital games, special populations (e.g., students with disabilities or gifted learners) to reduce bias, as well as theoretical articles, literature reviews, editorials, book chapters, and conference papers. Additionally, studies reporting only indirect outcomes (e.g., motivation without academic performance data) or lacking full-text availability were omitted.

Screening and Selection Process

A four-stage PRISMA flow was followed: *identification*, *screening*, *eligibility*, and *inclusion*. The initial search yielded 16,315 records. After removing duplicates, 826 articles remained for title and abstract screening. Based on relevance and inclusion criteria, 257 articles proceeded to full-text assessment. Of these, 17 studies met all inclusion criteria and were retained for final synthesis. The screening process followed guidelines adapted from Margot & Kettler (2019), Mohamed Shaffril et al. (2021) and is illustrated in Figure 1.

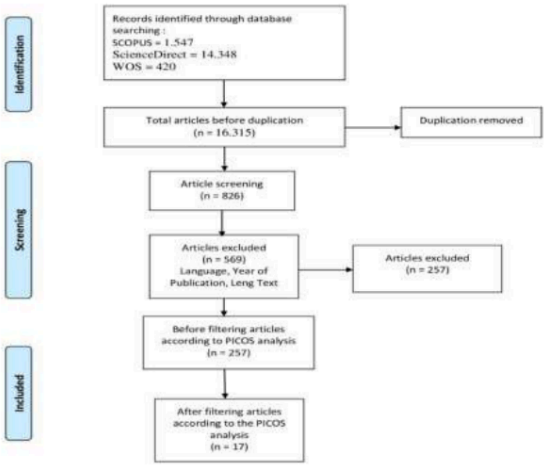

Figure 2. PRISMA flow diagram

Quality Appraisal

The quality of the included studies was evaluated using the CASP checklist to ensure methodological rigor, design clarity, and outcome reliability. Only studies scoring ≥70% were included. Potential biases, such as publication and selection bias, were minimized through comprehensive database searches and multi-stage screening. Formal funnel plot analysis was omitted due to the qualitative synthesis. Two independent reviewers conducted the appraisal, resolving discrepancies through consensus to maintain objectivity.

Data Extraction and Synthesis

This review adhered to PRISMA 2020 guidelines (Page et al., 2021) to ensure transparency and replicability. A structured coding matrix in Excel captured essential study details: authors, year, country, method, participants, intervention type, cognitive and affective outcomes, instruments, and main results. Thematic synthesis combined inductive and deductive approaches; predefined themes (cognitive vs. affective) were expanded via open coding into subthemes like reasoning, engagement, and anxiety reduction. Studies were categorized by education level, game type (digital, non-digital, gamification), and regional context (developed vs. developing), enabling pattern comparison. Two independent reviewers conducted data extraction and coding; discrepancies were resolved by consensus. Cohen's Kappa (0.81) confirmed substantial inter-rater reliability. Due to methodological heterogeneity, meta-analysis was not performed; instead, descriptive statistics and narrative synthesis summarized findings and gaps. Themes were validated through peer debriefing to ensure trustworthiness. Table 2 summarizes the 17 included studies, highlighting intervention diversity and geographical distribution.

Table 2. Overview of Selected Studies on Game-Based Learning in Mathematics Education

Author(s)	Year	Country	Study Design	Game Type / Approach	Learning Focus	Outcomes Measured
Kiili et al.	2018	Germany	Experimental	Digital Rational Number Game	Fractions and Rational Number Concepts	Problem-solving, Engagement
Groening & Binnewies	2019	Germany	Between-Subjects	Gamification (Digital Rewards)	Motivation and Academic Performance	Motivation, Performance
Wardani et al.	2019	Indonesia	Quasi-Experimental	Digital Media + Gamified Tasks	3D Geometry (Cube Nets)	Achievement, Student Motivation
Abidin et al.	2019	Malaysia	Quasi-Experimental	Points & Badges Gamification	General Mathematics Concepts	Engagement, Performance
Barros et al.	2020	Portugal	Experimental	Serious Game	Polynomial	Conceptual

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Author(s)	Year	Country	Study Design	Game Type / Approach	Learning Focus	Outcomes Measured
				(Tempoly)	Operations	Understanding, Accuracy
Jiménez et al.	2020	Spain	Quasi-Experimental	Digital Escape Room	Algebra Learning	Motivation, Collaboration, Problem-solving
Legaki et al.	2020	Greece	Between-Subjects	Challenge-Based Gamification	Statistical Literacy	Achievement, Cognitive Load
Yung et al.	2020	Hong Kong	Experimental	Hybrid Card & QR Game	Percentages and Fractions	Engagement, Performance
Leonardou et al.	2020	Greece	Experimental	Game-Based Assessment Tools	Learner Motivation Strategies	Engagement, Improvement Tracking
Rosillo & Montes	2021	Spain	Quasi-Experimental	Dual-Mode Escape Room	Remote Algebra Instruction	Cognitive Engagement, Motivation
Chiu & Seah	2024	Singapore	Quasi-Experimental	Contextual Gamified Tasks	Values-Based Math Teaching	Affective Dispositions, Value Alignment
Bayaga	2024	South Africa	Experimental	AI-Driven Learning Environment	Problem-Solving in Math Contexts	Reasoning, Achievement, Neural Network Performance Metrics
Zapata et al.	2024	Colombia	Quasi-Experimental	3D Augmented Reality Game	Geometry Learning via Immersion	Conceptual Understanding, Student Interest
Christopoulos et al.	2024	Greece	Experimental	3D Virtual Immersive Game	Math Skill Improvement	Spatial Reasoning, Motivation
Ding & Yu	2024	Taiwan	Between-Subjects	Serious Games vs. Game Design	Science/Math Learning vs. Game Creation	Learning Gains, Gaming Duration, Interest
Choi et al.	2025	South Korea	Quasi-Experimental	Chess-Based Educational Game	Strategic Thinking in Math	Critical Thinking, Game-Driven Reasoning
Gui et al.	2025	China	Between-Subjects	Team-Based Collaborative Game	Group Learning in Math	Group Dynamics, Collaboration, Prior Knowledge Moderation

RESULT AND DISCUSSION

Results Contextual Mapping of Selected Studies

This review synthesizes findings from 17 peer-reviewed articles selected for their methodological rigor and relevance, sourced from Scopus, WOS, and ScienceDirect databases, including Q1 (n=13), Q2 (n=2), and Q4 (n=2) journals. The studies were analyzed across four dimensions: geographical origin, publication year, research method, and target educational level. Geographically, the studies span 13 countries, offering diverse educational and technological contexts. Southern and Western Europe contributed the most, notably

Greece (Christopoulos et al., 2024; Leonardou et al., 2020; Legaki et al., 2020) and Germany (Kiili et al., 2018; Groening & Binnewies, 2019), along with Portugal (Barros et al., 2020), Spain (Rosillo & Montes, 2021; Jiménez et al., 2020), Hong Kong (Yung et al., 2020), and Singapore (Chiu & Seah, 2024). The Global South is represented by Indonesia (Wardani et al., 2019), Malaysia (Abidin et al., 2019), South Africa (Bayaga et al., 2024), Colombia (Zapata et al., 2024), Taiwan (Ding & Yu, 2024), South Korea (Choi et al., 2025), and China (Gui et al., 2025).

This wide distribution reflects the global relevance of Game-Based Learning (GBL) in mathematics while revealing contextual differences. Studies from developing countries reported barriers such as limited infrastructure and teacher preparedness, whereas those from high-income nations emphasized sophisticated game design and seamless digital integration (Zapata et al., 2024; Choi et al., 2025). These disparities underscore the moderating role of local contexts in determining GBL effectiveness.

Figure 4. Distribution of Articles by Region

Publication Trends and Game Types in Reviewed Studies

As shown in Figure 3, the reviewed studies span from 2018 to 2025 with fluctuating publication trends. The earliest study appeared in 2018 (Kiili et al.), followed by three in 2019 (Wardani et al.; Abidin et al.; Groening & Binnewies) and five in 2020 (Leonardou et al.; Legaki et al.; Barros et al.; Yung et al.; Jimenez et al.), reflecting growing interest in GBL for mathematics. Only one study was published in 2021 (Rosillo & Montes), while no eligible studies were found for 2022–2023, indicating a potential publication gap. Interest resurged in 2024 with five studies (Christopoulos et al.; Chiu & Seah; Bayaga; Zapata; Ding & Yu), and continued with two in 2025 (Choi et al.; Gui), suggesting renewed focus in the post-pandemic era. DGBL consistently enhanced cognitive outcomes like problem-solving and reasoning (Kiili et al., 2018; Barros et al., 2020), whereas gamification boosted motivation and affective engagement (Groening & Binnewies, 2019).

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Regarding game types (Figure 4), three categories emerged: (1) Digital Game-Based Learning (DGBL), dominant in 11 studies (e.g., Kiili et al., 2018; Christopoulos et al., 2024); (2) Digital Gamification featured in four studies (Wardani et al., 2019; Gui et al., 2025); and (3) Non-Digital GBL applied in two studies (Bayaga et al., 2024; Choi et al., 2025). This distribution confirms DGBL's prevalence, likely due to its adaptability, interactivity, and compatibility with modern educational needs.

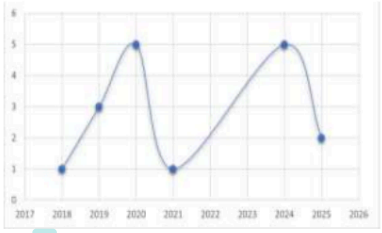

Figure 5. Distribution of Articles by Year

Figure 6. Distribution of Articles by Game Type

Research Design and Educational Context Distribution

As shown in Figure 7, the reviewed studies applied three main research designs: true experimental (7 studies), between-subjects experimental (4 studies), and quasi-experimental (7 studies). True experimental designs, involving random group assignment and controlled interventions, were used by Kiili et al. (2018), Barros et al. (2020), Bayaga et al. (2024), Yung et al. (2020), Leonardou et al. (2020), and Christopoulos et al. (2024). Between-subjects designs without randomization were employed in studies such as Gui et al. (2025), Ding & Yu (2024), Groening & Binnewies (2019), and Legaki et al. (2020). Quasi-experiments, lacking random assignment but involving intervention and control groups, were seen in Jimenez et al. (2020), Choi et al. (2025), Chiu & Seah (2024), Wardani et al. (2019), Abidin et al. (2019), Rosillo & Montes (2021), and Zapata et al. (2024).

Regarding educational levels (Figure 8), studies were categorized into three groups: (1) elementary/lower secondary (4 studies, e.g., Kiili et al., 2018; Choi et al., 2025; Chiu & Seah, 2024; Leonardou et al., 2020), (2) junior secondary (4 studies, e.g., Wardani et al., 2019; Abidin et al., 2019; Jimenez et al., 2020; Barros et al., 2020), and (3) combined junior–senior secondary (9 studies, e.g., Gui et al., 2025; Ding & Yu, 2024; Groening & Binnewies, 2019; Legaki et al., 2020; Bayaga et al., 2024; Yung et al., 2020; Rosillo & Montes, 2021; Zapata et al., 2024; Christopoulos et al., 2024). These classifications highlight methodological diversity

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and the broad application of GBL across age groups in mathematics education.

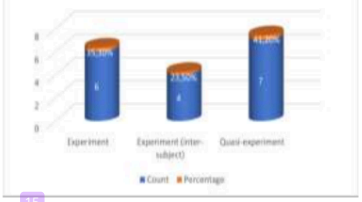

Figure 7. Distribution of articles based on research methods

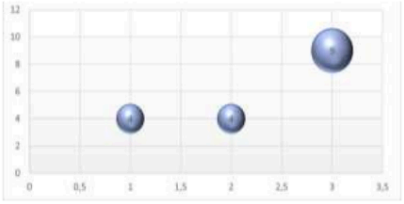

Figure 8. Distribution of articles based on education level

Thematic Trends in Game-Based Learning Research in Mathematics Education

An analysis of 17 reviewed articles identified nine key thematic areas in game-based learning (GBL) for mathematics: (1) problem-solving, (2) learning motivation, (3) general mathematics education, (4) algebra, (5) foundational skills, (6) rational numbers, (7) polynomial operations, (8) statistics, and (9) geometry (cube nets) (see Figure 9). Longer interventions (Gui et al., 2025; Zapata et al., 2024) produced more sustained cognitive and affective improvements, while short-term implementations primarily boosted immediate engagement. Problem-solving and motivation were the most frequent themes, each explored in three studies (Bayaga et al., 2024; Christopoulos et al., 2024; Ding & Yu, 2024; Groening & Binnewies, 2019; Legaki et al., 2020; Gui et al., 2025), emphasizing the role of GBL in enhancing reasoning skills and intrinsic motivation. General mathematics education also featured prominently (Abidin et al., 2019; Chiu & Seah, 2024; Zapata et al., 2024), alongside specific content areas such as algebra (Rosillo & Montes, 2021; Jiménez et al., 2020) and basic skills (Yung et al., 2020; Leonardou et al., 2020). Less-explored topics included rational numbers (Kiili et al., 2018), polynomials (Barros et al., 2020), statistics (Legaki et al., 2020), and geometry (Wardani et al., 2019), indicating potential for further research.

Despite GBL's promise in improving motivation and engagement, its effect on higher-order cognitive skills remains inconsistent, especially in short-duration or low-resource contexts. This suggests that GBL success depends not only on game design but also on systemic factors like infrastructure, teacher readiness, and cultural perceptions of technology (Gui et al., 2025; Ding & Yu, 2024). Moreover, the limited use of standardized affective measures (Radkowitsch et al., 2021) raises concerns about the validity of affective outcome assessments. The underrepresentation of themes such as statistics, spatial geometry, and

polynomial operations highlights the need for broader GBL content coverage in future studies.

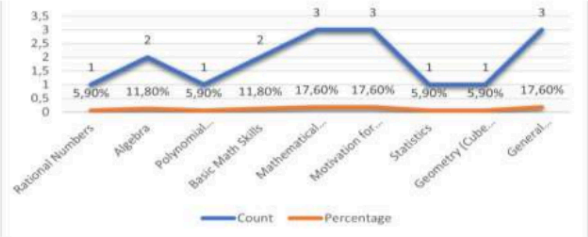

Figure 9. presents the distribution of articles based on their respective research topics.

Discussion

The Impact of Game-Based Learning (GBL) on Students' Cognitive Domain in Mathematics Education.

Analysis of 17 reviewed articles consistently shows that GBL positively impacts students' cognitive abilities in mathematics, particularly in enhancing conceptual understanding, problem-solving, and higher-order thinking skills such as critical and creative thinking. Kiili et al. (2018) demonstrated that game metrics could predict learning outcomes, with students outperforming control groups in rational number tasks. Similarly, Jimenez et al. (2020) and Barros et al. (2020) reported that digital games like Escape Room and Tempoly significantly improved both engagement and achievement in algebra and polynomial operations. GBL also enhances problem-solving abilities, especially among students with high prior knowledge in collaborative settings (Gui et al., 2025). Bayaga et al. (2024) found that AI-based digital GBL improved thinking skills. Visual-rich content, such as geometry and 3D objects, further benefits from GBL through digital and AR platforms (Wardani et al., 2019; Zapata et al., 2024), while hybrid models (Yung et al., 2020; Rasillo & Montes, 2021) yield positive post-test outcomes across diverse instructional formats.

From a pedagogical perspective, game-based challenges in statistics (Legaki et al., 2020) and reward systems (Leonardou et al., 2020) enhance cognitive performance, supported by immersive 3D technologies (Christopoulos et al., 2024). These findings align with Constructivist Learning Theory, emphasizing knowledge construction via active, engaging tasks, and with Cognitive Load Theory, where well-designed multimodal content facilitates understanding, especially in spatial domains like geometry. However, variations in research

settings, sample sizes, and educational contexts limit broad generalization. Factors such as technological infrastructure, teacher readiness, and cultural attitudes toward digital learning may influence GBL effectiveness, especially in resource-constrained environments. Future research should address long-term impacts, skill transferability across mathematical domains, and differential effects on diverse learner profiles.

The Impact of Game-Based Learning (GBL) on Students' Affective Domain in Mathematics Education.

Game-Based Learning (GBL) positively influences students' affective domain by enhancing motivation, emotional engagement, positive attitudes, and reducing mathematics anxiety, as reported in seven of the 17 reviewed studies. These improvements align with Self-Determination Theory (Deci & Ryan, 2000), which highlights autonomy, competence, and relatedness as drivers of intrinsic motivation. Positive feedback, reward systems, and challenge-based mechanics (Leonardou et al., 2019; Jimenez et al., 2020) were key factors meeting these psychological needs. For example, Jimenez et al. (2020) demonstrated that Digital Escape Rooms not only improved algebra outcomes but also increased student motivation. Similarly, Groening & Binnewies (2019) found gamification elements like badges and leaderboards enhanced engagement and confidence, while Leonardou et al. (2019) showed that well-designed feedback reshaped students' perception of mathematics as enjoyable and stimulating. Choi et al. (2025) reported that non-digital chess-based GBL fostered active engagement and a competitive spirit. Studies using AR and dual-mode escape rooms (Zapata et al., 2024; Rasillo & Montes, 2021) provided immersive experiences, promoting comfort and interest in mathematics.

However, some studies (e.g., Ding & Yu, 2024) only briefly addressed affective outcomes without standardized instruments, limiting result comparability. Variations in game duration, complexity, and contextual relevance may explain inconsistencies. The general trend suggests GBL enhances motivation and reduces anxiety, but reliance on self-reports raises concerns of bias. Future research should employ multi-method assessments, such as behavioral and physiological measures, for more valid affective evaluation.

Key Themes in the Implementation of Game-Based Learning (GBL)

This systematic review identifies four key themes that bridge cognitive, affective, and contextual aspects of GBL in mathematics education an integrative perspective rarely emphasized in prior studies. These themes reflect prevailing trends, existing gaps, and opportunities for future pedagogical refinement.

1. Dominance of Digital Platforms Digital platforms dominate GBL implementation, with 10 of 17 studies employing tools such as escape rooms (Jimenez et al., 2020; Zapata et al., 2024), 3D virtual environments (Christopoulos et al., 2024), gamification systems (Leonardou et al., 2020), and AR/AI-based simulations (Bayaga et al., 2024; Yung et al., 2020). These studies affirm the central role of technology in enhancing engagement, interactivity, and real-time feedback, aligning with 21st-century learning demands.
2. Focus on Problem-Solving and Higher-Order Thinking. Nine studies emphasized problem-solving and critical thinking, particularly at the upper secondary level, where students are more prepared for complex, challenge-based tasks. GBL was strategically employed to develop analytical reasoning and conceptual depth through interactive problem scenarios (Barros et al., 2020; Gui et al., 2025).
3. Enhancing Motivation and Engagement. Seven studies highlighted GBL's effectiveness in boosting motivation and positive attitudes towards mathematics. Elements such as rewards, instant feedback, and collaborative challenges (Groening & Binnewies, 2019; Jimenez et al., 2020; Choi et al., 2025) fostered intrinsic motivation, emotional involvement, and classroom enthusiasm.
4. Global Adoption and Contextual Variations. The reviewed studies spanned diverse regions of Europe, Asia, Africa, and Latin America, demonstrating GBL's adaptability across cultures and educational systems (Zapata et al., 2024; Rasillo & Montes, 2021). These variations reflect differences in technological readiness, curriculum structures, and cultural values, shaping both implementation and outcomes.

However, a notable limitation is the predominance of short-term interventions, raising concerns about the sustainability of GBL's cognitive and affective benefits. This highlights the need for longitudinal research to evaluate its long-term impact on mathematical learning outcomes.

Contextual Factors Influencing the Effectiveness of Game-Based Learning (GBL)

The success of GBL in mathematics education is shaped not only by game type but also by key contextual factors identified in 17 reviewed studies: student characteristics, game design, intervention duration, and teacher readiness with infrastructure support.

1. Student Characteristics Students' prior knowledge and metacognitive skills influence GBL outcomes, as demonstrated by Gui et al. (2025), who found that learners with stronger prior knowledge performed better in collaborative settings. This underscores the

importance of adapting GBL to students' readiness levels, aligning with Constructivist Learning Theory (Piaget, 1970; Vygotsky, 1978).

2. Type and Design of Games. GBL effectiveness depends on the game's format: digital GBL (e.g., AR, 3D simulations) fosters conceptual understanding and engagement (Kiili et al., 2018; Zapata et al., 2024), digital gamification (e.g., points, badges) boosts routine task motivation (Groening & Binnewies, 2019), while non-digital GBL (e.g., chess games) enhances interaction and critical thinking, especially in low-tech settings (Choi et al., 2025). Thus, game choice must align with learners' needs and resource availability (Zapata et al., 2024).
3. Duration and Intensity of Intervention. Short-term GBL interventions increase motivation but yield transient effects (Leonardou et al., 2020); longer, repeated applications produce more stable cognitive and problem-solving gains (Gui et al., 2025; Zapata et al., 2024). However, inconsistent reporting on duration limits cross-study comparability, emphasizing the need for standardized intervention descriptions.
4. Teacher Readiness and Infrastructure. Teacher competence and infrastructure quality are crucial. Lack of training and limited digital skills hinder GBL use (Wardani et al., 2019), as does insufficient technological access (Ding & Yu, 2024). Successful GBL implementations require technical support, policy backing, and institutional commitment.

In sum, while GBL holds potential to enhance cognitive and affective outcomes in mathematics, its success relies heavily on these contextual factors. Adaptive strategies, mixed-methods research, and validated tools are needed to capture long-term impacts, especially in resource-limited contexts. Policymakers should promote low-cost, culturally relevant non-digital GBL to bridge technological gaps, and future studies should explore moderators such as socio-economic status, digital literacy, and gender.

CONCLUSION

This systematic review synthesized findings from 17 empirical studies (2018–2025) on the impact of Game-Based Learning (GBL) in mathematics education. Results consistently showed that GBL enhances cognitive skills such as conceptual understanding, problem-solving, and higher-order thinking (critical and creative), improving performance in algebra, statistics, and geometry. Digital tools like escape rooms, AR/3D environments, and gamified platforms proved particularly effective in promoting deep learning and engagement. GBL also positively influenced affective outcomes by increasing motivation, reducing math anxiety,

and fostering positive attitudes. However, most studies lacked standardized, psychometrically sound instruments for measuring affective impacts, indicating a need for stronger methodological rigor.

Contextual factors, student characteristics, game design quality, intervention duration, and teacher readiness were critical, with game design and teacher competence as key determinants. A disparity remains between digital GBL in well-resourced settings and the relevance of non-digital games in limited-resource environments, reflecting a global digital divide. Overall, GBL offers a promising approach to integrating cognitive and affective learning. Future efforts should focus on contextualized game design, comprehensive teacher training, and equitable technology access, aligning with Indonesia's *Kurikulum Merdeka* and 21st-century education goals. Further research is needed to establish standardized affective assessment tools and evaluate GBL's long-term impacts across varied contexts.

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