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Trends and Directions of Gamification Research in Mathematics: Systematic Literature Review

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a r t i c l e i n f o

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a b s t r a c t

Mathematics education plays a crucial role in equipping students with the skills necessary for the 21st century, such as critical thinking and problem-solving abilities. However, many students perceive mathematics as a challenging and tedious subject, which ultimately leads to a decline in their motivation and learning outcomes. Consequently, the application of gamification as an alternative method in mathematics instruction has demonstrated significant potential for enhancing student engagement and learning results. This research aims to investigate the impact of gamification in mathematics learning, as well as the trends associated with its implementation. Findings from prior studies indicate that gamification, whether digital or non-digital, can enhance motivation, reduce mathematics-related anxiety, and deepen the understanding of mathematical concepts. Digital educational games, along with the use of non-digital playing cards, have proven effective in improving student engagement and comprehension of mathematics across various educational levels. Adaptive learning systems that utilize artificial intelligence (AI) also exhibit substantial potential in providing personalized learning experiences tailored to the abilities of individual learners. This article examines 13 prominent journals selected following a rigorous elimination process utilizing the systematic literature review methodology. This process will occur from 2015 until 2025. The objective of this systematic approach is to evaluate and analyze pertinent, high-quality literature to enhance comprehension of the subject matter. The PRISMA approach is utilized to choose articles based on the established inclusion and exclusion criteria to get pertinent literature. Nevertheless, the challenges faced include the creation of gamification that is both more immersive and relevant to real-life contexts. Further research is required to explore the implementation of more pertinent gamification elements, such as challenges based on real-world situations and aspects of robotics, as well as the influence of social and emotional factors on the effectiveness of gamification in mathematics education. Thus, this study contributes to identifying the potential and shortcomings in the application of gamification within the field of mathematics education.

a b s t r a k

Pendidikan matematika memainkan peran krusial dalam membekali siswa dengan keterampilan yang dibutuhkan untuk abad ke-21, seperti berpikir kritis dan kemampuan memecahkan masalah. Namun, banyak siswa menganggap matematika sebagai mata pelajaran yang menantang dan membosankan, yang pada akhirnya menyebabkan penurunan motivasi dan hasil belajar mereka. Akibatnya, penerapan gamifikasi sebagai metode alternatif dalam pengajaran matematika telah menunjukkan potensi yang signifikan untuk meningkatkan keterlibatan dan hasil belajar siswa. Penelitian ini bertujuan untuk menyelidiki dampak gamifikasi dalam pembelajaran matematika, serta tren yang terkait dengan implementasinya. Temuan dari studi sebelumnya menunjukkan bahwa gamifikasi, baik digital maupun non-digital, dapat meningkatkan motivasi, mengurangi kecemasan terkait matematika, dan memperdalam pemahaman konsep matematika. Permainan edukasi digital, bersama dengan penggunaan kartu remi non-digital, telah terbukti efektif dalam meningkatkan keterlibatan dan pemahaman matematika siswa di berbagai jenjang pendidikan. Sistem pembelajaran adaptif yang memanfaatkan kecerdasan buatan (AI) juga menunjukkan potensi substansial dalam menyediakan pengalaman belajar yang dipersonalisasi yang disesuaikan dengan kemampuan masing-masing peserta didik. Artikel ini mengkaji 13 jurnal terkemuka yang dipilih setelah proses eliminasi yang ketat menggunakan metodologi tinjauan pustaka sistematis. Proses ini akan berlangsung dari tahun 2015 hingga 2025. Tujuan dari pendekatan sistematis ini adalah untuk mengevaluasi dan menganalisis literatur yang relevan dan berkualitas tinggi untuk meningkatkan pemahaman tentang pokok bahasan. Pendekatan PRISMA digunakan untuk memilih artikel berdasarkan kriteria inklusi dan eksklusi yang ditetapkan untuk mendapatkan literatur yang relevan. Namun demikian, tantangan yang dihadapi termasuk penciptaan gamifikasi yang lebih mendalam dan relevan dengan konteks kehidupan nyata. Penelitian lebih lanjut diperlukan untuk mengeksplorasi penerapan elemen gamifikasi yang lebih relevan, seperti tantangan berdasarkan situasi dunia nyata dan aspek robotika, serta pengaruh faktor sosial dan emosional terhadap efektivitas gamifikasi dalam pendidikan matematika. Dengan demikian, penelitian ini berkontribusi untuk mengidentifikasi potensi dan kekurangan dalam penerapan gamifikasi dalam bidang pendidikan matematika.

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1. Introduction

Mathematics education plays a pivotal role in preparing students with essential 21st-century competencies. Beyond numerical literacy and formulaic knowledge, it fosters critical thinking and problem-solving skills that are increasingly important in today's society (Firdaus & Mukhtar, 2020; Toheri *et al.*, 2020; Trisnani *et al.*, 2024). In an era shaped by rapid technological advancement and the widespread use of information, mathematical proficiency is fundamental for interpreting and analyzing data. Competencies such as mathematical modeling, data analysis, and deductive reasoning enable students to make well-informed decisions in both personal and professional settings (Jawad, 2022). Therefore, mathematics literacy is essential for enhancing one's ability to reason and act effectively. Despite its significance, mathematics is frequently perceived by students as difficult and monotonous, often leading to decreased interest, diminished intrinsic motivation, and poor academic outcomes (Milovanović, 2020; Zanabazar *et al.*, 2023). Many learners feel confined within repetitive instructional routines where abstract and complex concepts are presented in ways that fail to engage or facilitate understanding (Smith & Fotou, 2023).

As a result, students may develop frustration and disengage from learning activities, exacerbating gaps in comprehension especially when personalized support is lacking. Addressing this challenge requires the implementation of innovative pedagogical strategies. One promising approach is gamification, which incorporates elements such as points, leaderboards, and rewards to foster student engagement and motivation. This method has been shown to encourage greater participation and improve academic performance by creating a more enjoyable and interactive learning environment (Pradana *et al.*, 2023; Salah & Alzaghal, 2023). According to Lee *et al.* (2023), gamification significantly enhances student involvement and enthusiasm in mathematics instruction. Similarly, Li *et al.* (2023) found that incorporating games in classroom activities promotes motivation, engagement, curiosity, and improved learning outcomes. Together, these findings support the effectiveness of gamification in boosting student learning and academic achievement across disciplines. Through the adoption of gamification, it is anticipated that learners will become more actively engaged and motivated to approach mathematics in ways that are meaningful and stimulating. While the use of gamified methods has gained traction in various instructional settings, including general education and language learning, its application within mathematics remains relatively underdeveloped and lacks a clearly defined structure (Morocho Palacios *et al.*, 2023). This reflects an ongoing gap in the application of gamification strategies specifically tailored to mathematics learning. This study seeks to address these issues by examining how gamification can support the teaching and learning of mathematics, especially in relation to the challenges inherent in the subject. The research focuses on two central questions: (i) What is the impact of gamification on students' mathematics learning outcomes? and (ii) What are the prevailing trends in the integration of gamification in mathematics education?

2. Research Methodology

This study adopts a Systematic Literature Review (SLR) methodology to identify the primary themes, directions, and research patterns related to the use of gamification in mathematics education. The SLR approach was chosen for its effectiveness in systematically locating, evaluating, and synthesizing all relevant studies aligned with a defined topic (Fundoni *et al.*, 2023). The review focuses on journal articles indexed in the Scopus database and published between 2015 and 2025. To conduct the literature search, the following keywords were applied: "Gamification," "Game-Based Learning," "Mathematics," "Math," and "Matematika." The final search string was constructed as: ("Gamification" OR "Game-Based Learning") AND ("Mathematics" OR "Math" OR "Matematika"). The selection and analysis of sources were carried out in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, which involves four key phases: identification, screening, eligibility assessment, and final inclusion. In the initial stages, specific inclusion criteria were established to ensure that only studies explicitly addressing gamification in mathematics education were considered.

The review also applied publication date restrictions, ensuring that only literature published within the 2015–2025 timeframe was analyzed to maintain data relevance and recency.

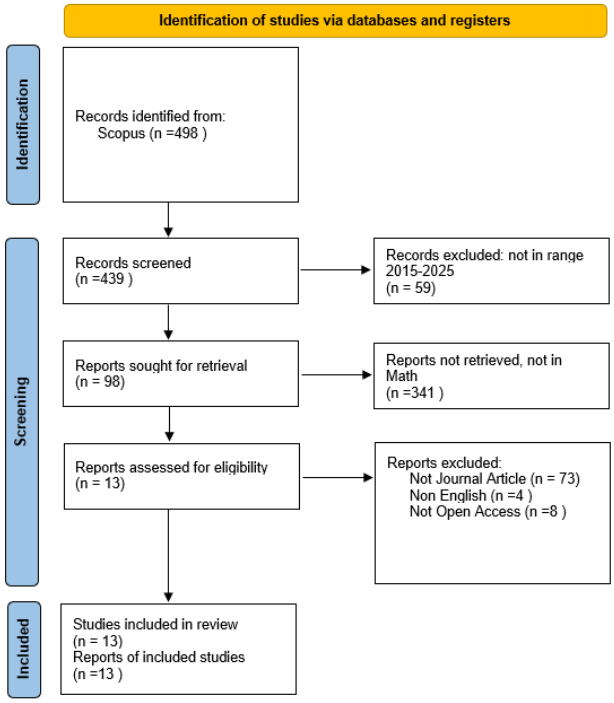

Figure 1. PRISMA flow diagram

A total of 498 articles were identified from Scopus. Out of these 498 articles, 59 were excluded as they were published outside the timeframe of 2015 to 2025, leaving a remainder of 439 articles. Subsequently, a further selection was made to ensure that the articles fell within the scope of mathematics. It was found that 341 articles did not meet the criteria, resulting in a final count of 98 articles. Upon further scrutiny of the 98 remaining articles, it was revealed that 73 were not journal articles, 4 were not in English, and 8 were not open access. Ultimately, after all selections were made, 13 articles were identified for analysis.

3. Results and Discussion

Results

In the article selection stage, based on the aforementioned criteria, the researcher was able to select only 13 articles that met the specified criteria, as outlined in Table 1.

Table 1. Author's name, year of publication, and title of the article

No	Author (Year)	Title
1	Gurjanow *et al.* (2019)	Mathematics Trails: Shallow and Deep Gamification
2	Greipl *et al.*(2020)	Different Performance, Full Experience: A Learning Game Applied Throughout Adulthood
3	Rocha & Dondio (2021)	Effects of a Video Game on Math Performance and Anxiety in Primary School
4	Rosillo & Montes (2021)	Escape Room Dual-Mode Approach to Teach Maths During the COVID-19 Era
5	Zabala-Vargas *et al.*, (2022)	Didactic Strategy Mediated by Games in the Teaching of Mathematics in First-Year Engineering Students
6	Alharthi *et al.* (2022)	Game-Based Learning in Primary Education: A Systematic Review of Literature
7	Hilario *et al.* (2022)	Gamification for Maths and Physics in University Degrees through a Transportation Challenge
8	Piñero Charlo *et al.* (2022)	Influence of the Algorithmization Process on the Mathematical Competence: A Case Study...
9	McMullen *et al.* (2023)	Mathematical Game Performance as an Indicator of Deliberate Practice
10	Dan *et al.* (2024)	Digital Game-based Learning in Mathematics Education at Primary School Level: A Systematic Literature Review

11	Almo *et al.*(2024)	Exploring the Impact of Player Traits on the Leaderboard Experience in a Digital Maths Game
12	Setambah *et al.* (2024)	Impact of 'Donkey', 'Snap', and 'King' Non-Digital Gamification Cards on Fourth-Grade Students' Math Performance in Fractions
13	Christopoulos *et al.* (2024)	Is Immersion in 3D Virtual Games Associated with Mathematical Ability Improvement...?

Table 2. Author's name, year of publication, and research methodology

No	Author (Year)	Method
1	Gurjanow *et al.* (2019)	Preliminary experimental study
2	Greipl *et al.*(2020)	Longitudinal study
3	Rocha & Dondio (2021)	Experimental study
4	Rosillo & Montes (2021)	Quasi-experimental study
5	Zabala-Vargas *et al.*, (2022)	Quasi-experimental study
6	Alharthi *et al.* (2022)	Systematic Literature Review (SLR)
7	Hilario *et al.* (2022)	Case study
8	Piñero Charlo *et al.* (2022)	Case study (Educational Escape Rooms)
9	McMullen *et al.* (2023)	Quantitative data analysis (game analytics)
10	Dan *et al.* (2024)	Systematic Literature Review (SLR)
11	Almo *et al.*(2024)	Quantitative study
12	Setambah *et al.* (2024)	Quasi-experimental study
13	Christopoulos *et al.* (2024)	Experiment (pre-post test)

Table 3. Author's name, year of publication, and key findings of the research

No	Author (Year)	Key Finding
1	Gurjanow *et al.* (2019)	Gamification in math trails with mobile and outdoor elements has great potential in education.
2	Greipl *et al.*(2020)	Educational games can be effectively applied across different age ranges, demonstrating lifelong learning potential.
3	Rocha & Dondio (2021)	Educational video games effectively reduce math anxiety and improve learning outcomes.
4	Rosillo & Montes (2021)	Educational escape rooms can be adapted to various learning modes, enhancing student motivation and understanding.
5	Zabala-Vargas *et al.*, (2022)	Educational games are effective in improving motivation and understanding of mathematical concepts in first-year engineering students.
6	Alharthi *et al.* (2022)	Game-based learning (GBL) is highly relevant for primary education in mathematics.
7	Hilario *et al.* (2022)	A gamified challenge with robotics is effective for learning mathematics and physics at the university level.

8	Piñero Charlo *et al.* (2022)	Gamification effectively reduces math anxiety and aids in the enjoyable assessment of numerical competence.
9	McMullen *et al.* (2023)	Performance in games can reflect deliberate practice, which is effective for adaptive learning.
10	Dan *et al.* (2024)	Digital games enhance mathematics learning through active engagement and increased motivation.
11	Almo *et al.*(2024)	Leaderboard features must be tailored to user characteristics for maximum effectiveness.
12	Setambah *et al.* (2024)	Non-digital gamification cards are effective in addressing misconceptions in fractions and enhancing student understanding.
13	Christopoulos *et al.* (2024)	Game-based learning (GBL) effectively improves mathematical abilities, though Immersion is not a key determinant.

The findings discussed above indicate that Zabala-Vargas *et al.* (2022) found educational game-based strategies to be effective in improving both engagement and mathematics learning outcomes among first-year engineering students. This outcome implies that such strategies not only foster motivation but also strengthen students' grasp of mathematical concepts. A longitudinal study by Greipl *et al.* (2020) further supports this by demonstrating that educational games can enhance learning performance across diverse age groups, irrespective of initial ability levels—highlighting their potential in supporting lifelong learning. Similarly, Dan *et al.* (2024) reported that digital game-based learning increases motivation and supports conceptual understanding in primary school mathematics.

Rocha and Dondio (2021) observed that educational video games contribute to reducing anxiety related to mathematics while improving academic performance. Additionally, Piñero Charlo *et al.* (2022) showed that a dual-mode escape room model, conducted both online and offline, successfully promotes motivation and improves mathematical comprehension. Technological advancements in education also show encouraging signs. Almo *et al.* (2024) emphasized the need to design leaderboard systems that align with individual learner profiles to maximize engagement and learning effectiveness in digital mathematics games. In parallel, Hilario *et al.* (2022) demonstrated that challenge-based gamification enhances participation and content relevance for university students in mathematics and physics, thus supporting its application at the tertiary level. Notably, non-digital gamification techniques also offer meaningful advantages. Setambah *et al.* (2024) confirmed that traditional playing cards contribute to better understanding of fractions among elementary school students. Piñero Charlo *et al.* (2022) reported reduced mathematics anxiety and improved mathematical competencies when gamified strategies were integrated into instruction. Christopoulos *et al.* (2024) observed notable gains in students' mathematical abilities following the use of virtual 3D games, even though these improvements were not directly linked to immersive depth. Meanwhile, McMullen *et al.* (2023) identified a positive correlation between in-game performance and numerical skill acquisition, suggesting that gameplay outcomes may serve as indicators of learning progression.

Gurjanow *et al.* (2019) distinguished between surface-level gamification, which generates initial motivation, and deeper forms of gamification that are still under development yet exhibit promising potential for mathematics instruction. These studies collectively affirm that gamification and game-based learning approaches significantly enhance student motivation, active involvement, and academic performance, particularly within mathematics education at various educational stages. The integration of such strategies can elevate the quality of instruction by encouraging participatory learning environments and dynamic interaction between learners and content. As a result, gamification emerges as an effective tool in subjects that are often perceived as intimidating or inaccessible. The implications of these findings are highly relevant for mathematics educators. Designing lessons that integrate game elements in a purposeful way is critical to fostering learner interest and supporting individualized instruction. Strategies

should not only engage but also accommodate the unique learning characteristics of each student to yield optimal educational outcomes. Moreover, the combined use of digital and traditional learning tools adapted to classroom settings may serve as an effective means of maintaining student motivation and reducing the anxiety often associated with mathematics. This strategy is particularly valuable in remote or hybrid learning settings, where students may face greater barriers to engagement. Implementing enjoyable and flexible approaches in such environments can support the development of more effective and supportive learning atmospheres. In response to the research question, "What are the trends in gamification within mathematics education?", it is clear that both digital and non-digital gamification approaches have consistently demonstrated a positive impact on student motivation and learning outcomes, particularly in mathematics. Educational games in various forms have been shown to improve conceptual understanding, reduce anxiety, and strengthen students' grasp of mathematical principles. Existing studies reveal that gamification fosters active participation, encourages more effective instructional delivery, and allows for the personalization of teaching strategies to address individual learning needs. Gamification also supports sustained interest in learning across different educational stages, ranging from elementary to tertiary levels.

As a result, it contributes significantly to the development of foundational and advanced mathematical competencies. Gamified learning environments whether through structured challenges, point systems, or interactive technologies show promising effects in enhancing numerical fluency and working memory, both of which are essential to success in mathematics. Nevertheless, despite the numerous studies highlighting the benefits of gamification, some findings point to inconsistencies. While gamified approaches can increase engagement and short-term motivation, their long-term influence on academic performance and conceptual comprehension is not always conclusive. For instance, research by Fuchs (2022) and X. Li *et al.* (2024) suggests that although gamification may reduce anxiety and boost enthusiasm temporarily, its enduring impact on learning outcomes remains limited. Similarly, studies by Celis *et al.* (2023) and Garcia-Iruela *et al.* (2020) indicate that heightened engagement does not necessarily translate to measurable academic improvement. These mixed results may be attributed to several variables, including the learner's cognitive profile, instructional context, and the specific mechanics employed in the gamified activity. Recent literature suggests a growing trend toward integrating both digital and analog tools in classroom practice. Digital games are particularly effective in promoting curiosity, conceptual understanding, and sustained focus across educational levels. In addition, adaptive learning platforms powered by artificial intelligence (AI) present opportunities to design learning pathways tailored to individual student abilities and progress. Meanwhile, traditional gamification methods such as playing cards continue to prove useful in reinforcing key mathematical concepts, particularly at the foundational level. Several studies also underscore the importance of aligning gamification features, such as competition formats or leaderboard structures, with learner profiles to ensure that the motivational effect is sustained. In parallel, efforts to design more immersive gamified experiences such as those involving real-life problem-solving scenarios or robotics-based tasks are emerging as promising directions for developing meaningful and engaging mathematical instruction. Overall, the research indicates that gamification continues to evolve as a strategy that not only improves learner motivation and engagement, but also holds potential for transforming mathematics instruction into a more flexible, inclusive, and responsive learning experience.

Discussion

Following the selection process based on defined criteria, 13 peer-reviewed articles were identified for analysis. These studies present various methodological approaches and findings concerning the integration of gamification in mathematics education across different academic levels. Zabala-Vargas *et al.* (2022) found that game-mediated learning strategies improved motivation and conceptual understanding among first-year engineering students. Greipl *et al.* (2020), through a longitudinal study, confirmed that game-based learning enhanced performance across a wide age range, reinforcing its utility for lifelong education. Dan *et al.* (2024) emphasized that digital games support primary school students by promoting active engagement and conceptual clarity in mathematics. According to

Rocha and Dondio (2021), educational video games effectively reduce anxiety and improve mathematics performance. Similarly, Piñero Charlo *et al.* (2022) showed that a dual-mode escape room (both online and face-to-face) encouraged student motivation and facilitated better comprehension of mathematical concepts. In terms of instructional technology, Almo *et al.* (2024) stressed the need for leaderboard design to be responsive to player attributes in order to achieve optimal learning effects. Hilario *et al.* (2022) demonstrated that a challenge-based gamification model incorporating robotics led to increased engagement and content relevance, particularly for mathematics and physics at the tertiary level. Non-digital gamification approaches also showed promising results.

Setambah *et al.* (2024) reported that using non-digital playing cards enhanced students' understanding of fractions. Piñero Charlo *et al.* (2022) found that gamified strategies contributed to both reduced anxiety and the development of numerical competence. Christopoulos *et al.* (2024) observed a significant improvement in mathematical skills following the use of 3D virtual games, although the level of immersion was not a determining factor. Furthermore, McMullen *et al.* (2023) established that game performance can serve as a valid indicator of knowledge acquisition, especially in numerical domains. Gurjanow *et al.* (2019) distinguished between superficial gamification, which offers short-term motivation, and more complex designs that aim to deepen conceptual mastery. Collectively, the findings underscore that gamification and game-based learning promote higher levels of engagement and achievement in mathematics across academic settings.

These techniques foster participation and offer a more dynamic learning experience. From a pedagogical perspective, these insights hold practical relevance for mathematics educators. Designing learning environments that incorporate game elements should be prioritized to increase learner interest and responsiveness. Such approaches must also consider individual learner profiles to ensure that instructional methods align with cognitive and motivational needs. Incorporating both digital and non-digital activities into classroom instruction can improve student attention and reduce math-related anxiety. This strategy is particularly beneficial in remote learning scenarios, where disengagement tends to be more prevalent. Implementing engaging and interactive instructional formats is essential for establishing productive learning environments. In addressing the research question regarding current developments in gamification for mathematics education, the findings indicate a clear trend toward both digital and physical game-based techniques to enhance educational outcomes. Games regardless of format support the development of conceptual understanding and reduce apprehension toward mathematical material.

These tools also encourage sustained interaction and permit instructional adjustments tailored to individual needs. The utility of gamification has been demonstrated across grade levels, from elementary school through university, establishing its value in foundational and advanced mathematics instruction. Despite positive outcomes in many cases, certain studies present contradictory evidence. For instance, Fuchs (2022) and Li *et al.* (2024) observed that while gamification increased short-term motivation, it did not consistently lead to long-term academic gains or reductions in anxiety. In addition, Celis *et al.* (2023) and Garcia-Iruela *et al.* (2020) concluded that engagement through gamification does not always correlate with higher achievement, suggesting that individual learner differences and game design quality play a significant role.

Overall, recent studies point to a shift in mathematics education toward instructional models that integrate gamified experiences. Adaptive learning technologies powered by artificial intelligence offer personalized instruction tailored to student performance. Physical tools such as card games are similarly effective in reinforcing essential mathematical concepts. Further research into optimal game design such as matching leaderboard mechanics with learner profiles can support more effective educational outcomes. Meanwhile, efforts to incorporate robotics and real-world challenges into gamification strategies offer new directions for mathematics instruction that is engaging and practically relevant.

4. Conclusion

Based on the analysis of studies related to gamification in mathematics education, it can be inferred that both digital and non-digital gamification approaches substantially enhance students' motivation, participation, and academic achievement. Digital educational games have been shown to support the development of conceptual understanding while alleviating anxiety associated with mathematics. Meanwhile, non-digital methods, such as the use of playing cards, have proven effective in reinforcing foundational skills. This review also emphasizes the promise of adaptive learning systems powered by artificial intelligence, which enable personalized learning experiences aligned with individual learner profiles. Furthermore, the adjustment of specific game elements, such as leaderboards, to suit player characteristics is identified as a key factor in optimizing the effectiveness of gamified instruction. Nonetheless, challenges persist in designing gamification strategies that are not only pedagogically sound but also meaningfully connected to real-world experiences. Future investigations are encouraged to address less explored aspects, particularly in the advancement of gamification models and the incorporation of emerging technologies within mathematics learning.

Of particular importance is the examination of how elements like real-life problem-solving scenarios and robotics can be integrated to make learning experiences more applicable to students' daily lives. Moreover, greater attention should be paid to the role of social and emotional dimensions in gamified instruction, especially considering the diverse learning profiles that influence educational effectiveness. Longitudinal studies assessing the sustained impact of gamification on learning outcomes and study habits will also be crucial in determining its long-term viability. Despite growing empirical support, several gaps remain in the literature. One notable area is the limited application of gamification at the tertiary level, where its use remains sporadic compared to primary and secondary education. Although the use of digital educational games has been extensively studied, the implementation of structured gamification strategies to support advanced mathematical learning in higher education has received relatively little attention. Additionally, the development and evaluation of complex gamification systems that target abstract or higher-order mathematical concepts remain underrepresented. While recent efforts have begun to explore the alignment of gamified features with learner attributes, comprehensive investigations into how these adaptations interact with broader social and cultural contexts are still lacking. Consequently, further research is needed to explore how gamification can be systematically optimized for diverse learning environments and implemented effectively across various educational levels.

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