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META-ANALYSIS

Gamification on Mathematics Engagement and Motivation in Secondary School and Higher Education: A Systematic Review and Meta-Analysis

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Abstract

This systematic review and meta-analysis examined the effects of gamification on students' motivation and engagement in mathematics at the secondary and higher education levels. A literature search (April 2025) followed by an updated search (November 2025) across ten databases identified 45 studies for qualitative synthesis and 11 for meta-analysis. The review followed PRISMA 2020 guidelines with a pre-registered protocol, and study quality was appraised with the Mixed Methods Appraisal Tool. Meta-analytic results using a three-level Correlated and Hierarchical Effects model with robust variance estimation showed a significant small-to-moderate positive effect on motivation ($g = .383$, 95% CI [.11, .66], $p = .0218$). Motivation was assessed more consistently than engagement that could not be included in the meta-analysis due to the lack of validated measures. The systematic review indicates that gamification supports motivation and engagement, with only four studies reporting negative effects. Most interventions used digital platforms (e.g., *Kahoot!*; *Classcraft*) and common game elements such as points, leaderboards and instant feedback. Overall, gamification appears promising for enhancing motivation and engagement in mathematics when designs are aligned with students' needs, balancing competition with mastery and cooperation. Therefore, educators should limit excessive competition and prioritize personal progress and cooperative tasks that foster social interaction. Future studies should employ validated measures, larger samples, and examine both motivation and engagement to strengthen the evidence base and guide effective implementation in education.

Keywords Gamification · Mathematics · Meta-analysis · Motivation · Engagement

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Introduction

Mathematics has long been noticed by many students as a challenging and demotivating subject, regularly associated with high levels of anxiety, disengagement, and lack of motivation (Liebendörfer & Schukajlow, 2017). This perception is particularly evident at the secondary and higher education levels, where students face unique challenges in terms of motivation, engagement, and emotional responses (Pekrun et al., 2017). Thus, fostering a positive emotional connection and sustained motivation in mathematics is crucial to improve student engagement and academic success (Schukajlow et al., 2023).

Digital and game-inspired strategies have emerged as promising approaches to face these challenges, providing innovative methods to improve mathematics learning in secondary and higher education contexts (Faure-Carvallo et al., 2022). Among these, gamification, defined as the integration of game design elements (such as points, leaderboards, rewards, progression systems, and instant feedback) into non-game settings, has gained particular attention (Deterding et al., 2011). It should be distinguished from related approaches such as game-based learning and serious games. Gamification refers to adding specific game elements to non-game contexts, whereas game-based learning uses complete educational games as the primary learning activity (Plass et al., 2015). Serious games, by contrast, are digital simulations designed for training in applied fields like medicine, engineering, or aviation (Laamarti et al., 2014).

Gamification has emerged as a promising pedagogical strategy, with the potential to capture students' attention, foster active learning, and enrich the overall learning experience, particularly in subjects where disengagement and low motivation are common (Dichev & Dicheva, 2017). In mathematics, incorporating game elements into the curriculum can create more dynamic and interactive experiences, motivating students to participate more actively (Sailer & Homner, 2020; Subhash & Cudney, 2018). Gamified learning often relies on platforms such as *Khan Academy* or *Kahoot!* to embed elements like points, feedback, and leaderboards (Gurjanow et al., 2019), yet evidence of its effectiveness in enhancing motivation and engagement remains mixed (Ratinho & Martins, 2023).

Engagement, a multidimensional construct encompassing behavioral, emotional, and cognitive components (Fredricks et al., 2004; Reeve, 2024), is closely related but distinct from motivation, which represents the internal drive that initiates behavior. While motivation drives engagement, engagement reflects its visible manifestation in students' actions (Reeve, 2024). This interplay is particularly salient in gamified learning, where game elements are designed to stimulate motivation and foster engagement (García-López et al., 2023).

Still, gamification may produce unintended negative effects, especially in secondary and higher education (Elmawati et al., 2023; Ratinho & Martins, 2023). While some studies show positive outcomes (e.g., Sailer & Homner, 2020), others report declines in motivation due to competition, poor design, or reduced novelty (e.g., Hanus & Fox, 2015; Santhanam et al., 2016). These mixed findings highlight the need for further research to clarify the conditions under which gamification most effectively supports motivation and engagement in mathematics.

Motivational Theories Applied to Gamification in Education

Gamification can enhance students' motivation when grounded in established theories. As pointed by previous reviews (e.g., Alsawaier, 2018; Ratinho & Martins, 2023), Self-Determination Theory (SDT), the ARCS Model, Social Cognitive Theory (SCT), Achievement Goal Theory (AGT) and Flow Theory are among the most explored motivational frameworks in gamification research.

According to SDT, the satisfaction of autonomy, competence, and relatedness is essential to fostering intrinsic motivation (Deci & Ryan, 2000; Ryan & Deci, 2000, 2017). Gamified design elements can be aligned with these psychological needs, as points and levels may enhance perceptions of competence through progress feedback; avatars and collaborative features such as team leaderboards can strengthen relatedness; and opportunities to select tasks or difficulty levels may support autonomy (Hakulinen & Auvinen, 2014; Hanus & Fox, 2015; Jones et al., 2023).

The ARCS Model (i.e., Attention, Relevance, Confidence, and Satisfaction; Keller, 1987) also aligns with gamification. Attention can be captured through challenges or visual rewards; relevance by linking tasks to real-world goals; confidence by scaffolded levels; and satisfaction by immediate feedback or badges (Mese & Dursun, 2019; Özhan & Kocadere, 2020).

According to SCT (Bandura, 1977), self-efficacy beliefs play a central role in shaping motivation, influencing the choices individuals make, the effort they invest, and their persistence in the face of challenges. Gamification can support these through goal setting, feedback, and collaborative tasks that enable vicarious learning (Banfield & Wilkerson, 2014). For instance, gamified designs can strengthen students' self-efficacy when designed with progressive levels that move from simple to complex tasks, enabling learners to experience gradual mastery (Alsswey & Malak, 2024). In contrast, leaderboard features that emphasize constant peer comparison may undermine self-efficacy, particularly for lower-ranked students, unless carefully framed to support personal progress and collaboration (Santhanam et al., 2016).

AGT (Dweck, 1986) distinguishes mastery goals focused on learning, from performance goals focused on comparison. Gamification can encourage mastery via personal progress tracking, or performance through competitive leaderboards (Durmaz et al., 2022; Hakulinen & Auvinen, 2014).

Finally, Flow Theory (Csikszentmihalyi, 1990) suggests students achieve optimal engagement when challenges match skills. Gamified designs that balance difficulty and ability can help sustain motivation and foster a flow state (Khoshnoodifar et al., 2023; Oliveira et al., 2021).

Theories of Learning Engagement in Gamification

The most accepted framework for engagement is the multidimensional model (Fredricks et al., 2004), which includes three interrelated components: behavioral engagement (participation and effort), emotional engagement (feelings like interest or frustration), and cognitive engagement (mental investment and learning strategies).

Despite the growing use of gamification in educational contexts, engagement is often assessed through non-standardized indicators such as points, leaderboards, or task completion, which may not capture its full complexity (e.g., dos Santos et al., 2025; Khaleel et al., 2020; Zeybek & Saygi, 2023). Yet, some studies in secondary and higher education contexts have used validated tools to assess engagement. For example, the Student Course Engagement Questionnaire (SCEQ) (Handelsman et al., 2005) has been utilized to measure skill use, interaction, and emotional involvement (Feroz et al., 2020; Pimentel et al., 2022). The EGameFlow scale has been applied to assess dimensions such as concentration, feedback, autonomy, and challenge in gamified settings (Khoshnoodifar et al., 2023), capturing both engagement and flow-related constructs.

Justification, Aims and Research Questions

Numerous studies have examined the effects of gamification in education, but findings remain mixed. While some report improvements in intrinsic motivation and engagement, others suggest that these effects are limited or inconsistent (e.g., Hanus & Fox, 2015). Such discrepancies may stem from variations in implementation (González-Fernández et al., 2022), student characteristics, or subject areas (Oliveira et al., 2023).

In mathematics, particularly at the secondary and higher education levels, research remains scarce and often constrained by small samples or limited methodological rigor (Elmawati et al., 2023; Ratinho & Martins, 2023). These gaps make it difficult to draw firm conclusions and highlight the need for a systematic synthesis of available evidence in these contexts.

Accordingly, this review focuses on secondary and higher education, excluding preschool and primary levels due to their distinct motivational processes and pedagogical contexts. Whereas early mathematics emphasizes basic numeracy and playful learning, later stages involve more abstract, demanding and advanced content, where issues such as math anxiety and declining motivation and engagement become especially salient (Kaur et al., 2022; Pekrun et al., 2017).

Considering the above, the main objective of this systematic review and meta-analysis is to synthesize and evaluate the existing evidence on the effects of gamification on students' motivation and engagement in mathematics education at the secondary and higher education levels. Specifically, the review aims to answer the following research questions (RQ): RQ1: What are the methodological and contextual characteristics of the selected studies, and which gamification elements are most frequently implemented in mathematics education?; RQ2: Which theoretical frameworks support the use of gamification in mathematics education, and what instruments – along with their psychometric properties – are employed to assess student motivation and engagement?; RQ3: What is the overall effect of gamification on students' motivation and engagement in mathematics at the secondary and higher education levels?

By addressing these research questions, the review examines the effects of gamification on students' motivation and engagement in mathematics at the secondary and higher education levels. It also synthesizes key study characteristics (e.g., educational level, participant age, subject area), the instruments employed, and the motivational and engagement dimensions assessed, enabling a critical discussion of the scope and limitations of current evidence.

Method

This review followed the PRISMA guidelines (Page et al., 2021) and was registered in PROSPERO (ID—CRD42023481878). Studies were selected using predefined inclusion and exclusion criteria, framed by the PICO model: Population—secondary and higher education students in mathematics; Intervention—gamification strategies; Comparison—traditional, non-gamified instruction; Outcomes—effects on motivation and engagement. No date restrictions were applied, given the recent rise of gamification research (post-2010).

Eligibility Criteria

To ensure the selection of relevant studies that address the research aims, specific inclusion and exclusion criteria were applied. These criteria were designed to focus the review on quantitative studies that evaluate the effects of gamification on students´ motivation and engagement in the context of secondary school and higher education mathematics.

The following criteria were established for including studies in this review: 1) Quantitative Studies: Only studies employing quantitative research methods were included, as these provide measurable outcomes regarding the effects of gamification; 2) Exploration of Gamification: Studies must examine the impact or effect of gamification, defined as the use of game-like elements (e.g., points, badges, leaderboards) in educational settings to enhance student motivation and engagement; 3) Application in Mathematics Education: Eligible studies must focus on the application of gamification in mathematics education, including subfields such as geometry, statistics, algorithms, or algebra; 4) Education Level: Only studies involving students at the secondary or higher education were considered.

The exclusion criteria applied in this review were as follows: 1) Non-Gamification Studies: Studies that did not explored gamification—such as those focusing on virtual reality, educational games, or other unrelated instructional strategies—were excluded to ensure specificity of findings; 2) Qualitative Studies: Studies employing qualitative methodologies were excluded. While qualitative insights into gamification are valuable, they fall outside the scope of this quantitative synthesis; 3) Studies Focusing on Other Disciplines: Studies investigating gamification in disciplines other than mathematics were excluded to maintain a focused analysis; 4) Different Education Levels: Studies involving participants outside the target population—such as those in primary or early childhood education—were excluded.

Additionally, for inclusion in the quantitative analysis, studies had to compare a gamified group with a control group receiving traditional non-gamified instruction (e.g., standard exercises). Studies without such a comparison were excluded, as control groups are essential to assess gamification effects and calculate effect sizes.

Information Sources and Search Strategies

The review was conducted using predefined keywords, with the strategy adapted to each database (see Appendix Table 5). To address conceptual overlaps in the field, keywords such as "game-based learning," "serious games," and "educational games" were included (e.g., Becker, 2021; Ruiz et al., 2024; Warsinsky et al., 2021), though only studies consistent with the operational definition of gamification (i.e. the use of game elements in non-game contexts) were retained. For example, one study (Elizondo-Noriega et al., 2025) described its approach as gamification and game-based learning, but full-text inspection showed that students learned mathematics by playing a complete digital game, which aligns with Digital Game-Based Learning (see Online Resource 1).The term "STEM" was also used to capture mathematics studies indexed under this broader label, with non-mathematics studies excluded.

Searches were conducted in Scopus, ERIC, IEEE Xplore, MathSciNet, PsycINFO, Web of Science Core Collection, Zentralblatt MATH, ArXiv, Psychology and Behavioral Sciences Collection, and JSTOR, ensuring broad coverage of gamification research in mathematics education. As gamification of mathematics is a relatively recent research field, all relevant sources from the databases were considered, including conference papers and book chapters, to capture early empirical evidence and minimize publication bias (Siddaway et al., 2019).

Selection Process

The studies were independently assessed in multiple stages by two authors, with discrepancies resolved through consensus. The initial search was conducted on April 16 (2025) using predefined keywords across the selected databases. Duplicates were removed using Rayyan, a web-based screening tool designed to facilitate systematic reviews (Ouzzani et al., 2016). Titles and abstracts were screened for relevance, followed by full-text reviews based on the inclusion and exclusion criteria. A snowballing procedure yielded no additional studies. An updated search conducted on November 10 (2025) identified one additional eligible study. In total, 45 studies were included in the qualitative synthesis: 30 peer-reviewed journal articles, 14 conference papers, and one book chapter (Fig. 1). Of these, 11 studies (9 journal articles and 2 conference papers) met the criteria for the meta-analysis, while the remaining records were excluded due to the absence of control groups ($n=30$) or incomplete statistical data ($n=4$).

Quality Assessment of the Studies

The quality of the included studies was independently assessed by two authors using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). Disagreements were resolved through discussion. The MMAT evaluates methodological quality across five domains, making it appropriate for all studies in this review.

Meta-Analysis Procedures

Effect Size Calculation

Effect sizes were first computed as Cohen's d and then converted to Hedges' g using the correction factor J. This conversion is recommended for small to moderately

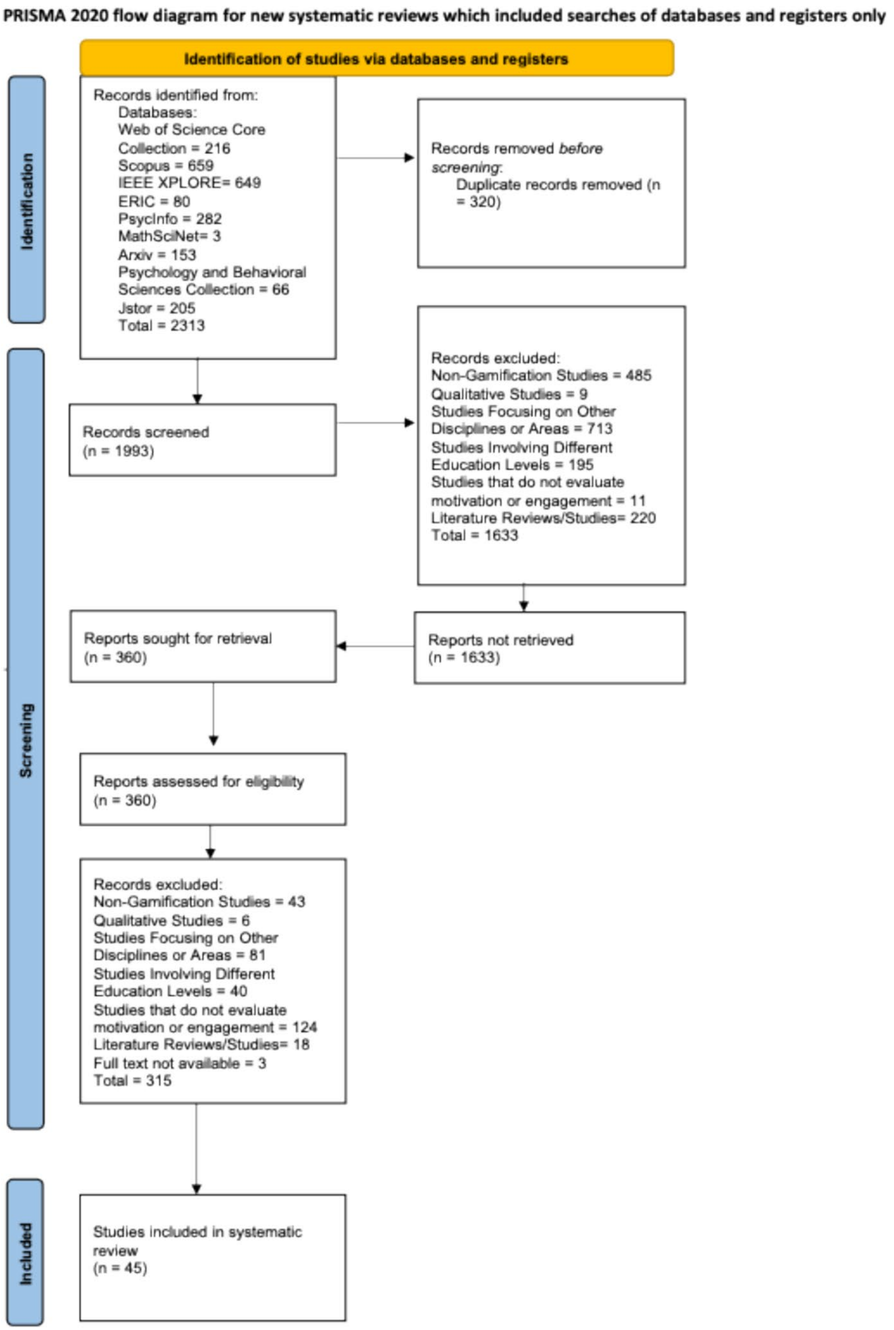

Fig. 1 PRISMA flow diagram. Note: Results reflect the merged output of the original search (April 2025) and an updated search (November 2025)

sized samples, typically studies with fewer than about 20 to 50 participants per group, and in cases of unequal sample sizes between the experimental and control groups, a condition met by several studies included in this review (Borenstein et al., 2009; Hedges & Olkin, 1985; Lakens, 2013; Turner & Bernard, 2006). Variances for Hedges' *g* were also calculated (Borenstein et al., 2009). A positive effect size reflects greater motivation in the gamified group relative to the control group within a specific motivational dimension or subscale. All computations were performed in RStudio (v4.4.2).

Power Analysis a Priori

An a priori power analysis was conducted to estimate the statistical power of the meta-analysis (Harrer et al., 2021), based on the 11 included studies and the average group sizes (n_1=44; n_2=35). Assuming a random-effects model with moderate heterogeneity, power was 61.82% for small effects (d=0.20), 99.43% for moderate effects (d=0.50), and 100% for large effects (d=0.80). Thus, the meta-analysis was well powered to detect moderate-to-large effects but underpowered for small effects, a common limitation in meta-analyses with relatively few studies (Valentine et al., 2010).

Meta-Analysis with Correlated and Hierarchical Effects and Robust Variance Estimation

The dataset comprised 29 effect sizes drawn from 11 independent studies. Several studies reported more than one motivational outcome (e.g., intrinsic and extrinsic motivation, self-efficacy, ARCS components), which were treated as statistically dependent because they originated from the same sample. Since pre-test measures were not consistently available across studies, only post-test scores were included in the analysis. This approach follows methodological guidance for handling heterogeneous pre–post reporting (Hornstein et al., 2025).

Because effect sizes within studies are statistically dependent, a three-level Correlated and Hierarchical Effects (CHE) model with Robust Variance Estimation (RVE) was used. This approach estimates random effects at both the study and within-study levels and provides small-sample-adjusted standard errors and confidence intervals (Harrer et al., 2021; Pustejovsky & Tipton, 2022). The working covariance matrix assumed ρ=.60, with sensitivity analyses conducted using ρ=.30 and ρ=.90 to assess robustness. Additional sensitivity analyses were performed using three alternative model specifications: a random-effects model with a single aggregated effect per study; a model restricted to peer-reviewed journal articles only; a quality-based sensitivity analysis excluding studies scoring ≤ 60% on the MMAT. All analyses were conducted in RStudio (v4.4.2) using appropriate meta-analytic packages, including *metafor* for model estimation, *clubSandwich* for robust variance estimation (CR2), and *dmetar* for diagnostic procedures (see Online Resource 2 for full code and procedures).

Influence diagnostics (Cook's distance, DFBETAS, hat values) were computed to evaluate whether individual effects disproportionately affected model estimates

(Viechtbauer & Cheung, 2010). Between and within-study heterogeneity were quantified using variance decomposition, Cochran's Q, and the I^2 statistic (Higgins & Thompson, 2002).

Tests for publication bias accounted for dependency among effect sizes. A funnel plot was generated using one aggregated effect per study, followed by an Egger-type meta-regression with RVE. PET-PEESE estimators (with RVE) were also used to obtain bias-adjusted effects under scenarios of zero or non-zero true effects (Stanley & Doucouliagos, 2014).

Moderator analyses were limited to single-moderator models due to the small number of clusters ($k=11$), as recommended for RVE applications (Harrer et al., 2021). Each moderator was entered separately using the same CHE-RVE structure.

Results

Quality Assessment

MMAT scores among the 45 included studies ranged from 20 to 100%. Most studies scored 60% ($n=26$), followed by 80% ($n=10$) and 40% ($n=7$); one study scored 100% and another scored 20%. When examined by publication type, peer-reviewed articles showed the full range of scores (20%—100%), whereas conference papers were mostly rated 60% ($n=8$) or 80% ($n=2$), with one paper at 40%. The single book chapter scored 60%. Overall, the modal score was 60%, indicating moderate methodological rigor across the evidence base. The most frequent methodological issues involved lack of randomization, limited control of confounders, incomplete reporting, and insufficient methodological detail (see Online Resource 3).

> **RQ1:** What are the methodological and contextual characteristics of the selected studies, and which gamification elements are most frequently implemented in mathematics education?

Among the 45 studies included in the qualitative analysis, the combined sample comprised a total of 4,345 students, including 2,435 from higher education and 1,910 from secondary school, with ages ranging from 13 to 38 years. Although several studies did not report the mean age, for the studies that reported it, the mean participant age was 17.92 years ($SD=2.35$).

Regarding education level, 17 articles focused on secondary school students, while 28 articles target higher education populations. The included studies originated from 23 countries, with the largest representation from Mexico and Spain ($n=5$, each), followed by the United States of America ($n=4$). Most articles addressed general Mathematics ($n=27$) followed by Statistics ($n=8$) and Calculus ($n=5$) subjects.

The gamification strategies varied considerably across studies, reflecting a wide range of applications used to support Mathematics learning. *Kahoot!* emerged as the most used tool, appearing in 9 studies ($n=9$). Additionally, some researchers developed customized applications to implement gamified strategies in the classroom (see Online Resource 4).

Publication dates for the included studies ranged from 2015 to 2025, showing a significant increase beginning in 2021 (Fig. 2). The highest number of publications was recorded in 2023.

Game elements were coded either as explicitly reported by the authors or, in cases where only the platform was specified, inferred from the documented features of the respective platform. According to that, the most frequent elements were points (*n* = 34), leaderboards (*n* = 31), feedback (*n* = 26), and levels (*n* = 23). Badges (*n* = 12), timers (*n* = 14), and rewards (n = 11) also appeared consistently, while missions (*n* = 3), narrative (*n* = 8), and progress bars (*n* = 6) were less common. Points were the most used element across both higher education (*n* = 23) and secondary school (*n* = 11) studies (Fig. 3).

> **RQ 2:** Which theoretical frameworks support the use of gamification in mathematics education, and what instruments – along with their psychometric properties – are employed to assess student motivation and engagement?

Motivation was assessed either as a unidimensional construct, treated as a general drive to learn and measured through a single global factor (*n* = 16), or as a multidimensional construct grounded in established motivational theories. Multidimen-

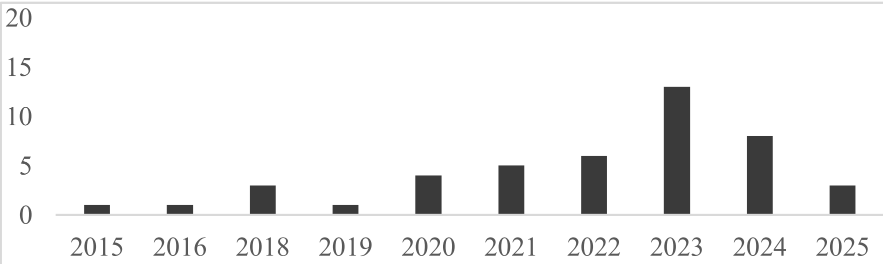

Fig. 2 Number of publications per year

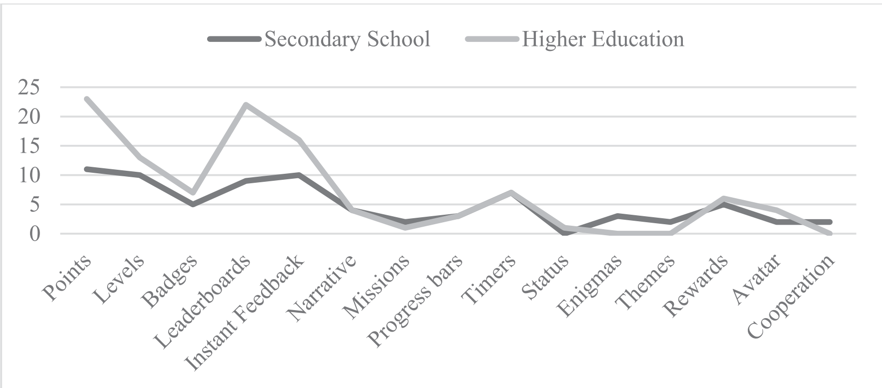

Fig. 3 Frequency of game elements in studies

sional approaches typically distinguished between intrinsic and extrinsic regulation or examined basic psychological needs (i.e. autonomy, competence, relatedness) as proposed by SDT, which was the most frequently used framework ($n = 13$). The ARCS model was also common, capturing Attention, Relevance, Confidence, and Satisfaction ($n = 6$), while SCT was used to assess self-efficacy beliefs ($n = 8$). AGT appeared in one study, distinguishing mastery and performance-oriented goals (Vandercruysse et al., 2015). Several studies also employed mathematics-specific motivation instruments (see Online Resource 5).

Engagement was assessed far less frequently. Only eight studies measured this construct, using either a unidimensional approach (Boom-Cárcamo et al., 2024; Chen et al., 2018; Lee et al., 2023; Wang et al., 2024) or specific subdimensions such as study-skills and interaction engagement (Feroz et al., 2020; Pimentel et al., 2022), cognitive and emotional engagement (Santos-Guevara et al., 2024), or behavioral engagement (Aljamaan et al., 2025). Notably, several studies did not report reliability estimates for their engagement measures.

> **RQ3:** What is the overall effect of gamification on students' motivation and engagement in mathematics at the secondary and higher education levels?

Several studies ($n = 16$) reported increases in students' overall motivation, conceptualized as a unidimensional construct, following the implementation of gamification (see Table 1). Within the SDT framework, most studies found increases in both intrinsic and extrinsic motivation (Khalid & Zainuddin, 2020; Kickmeier-Rust & Niggli, 2023; Ooge et al., 2024; Robinson et al., 2023). However, two studies reported declines in both types of motivation (Reyssier et al., 2022; Vandercruysse et al., 2015), and one found high motivational levels, but no significant gains compared with a control group (Dicheva et al., 2021).

Regarding SCT, most studies documented improvements in self-efficacy beliefs in mathematics (García-Hernández & González-Ramírez, 2021; Hammad et al., 2022; McIntyre, 2023; Montero-Izquierdo et al., 2024; Robinson et al., 2023), although one study reported a decline (García-López et al., 2023).

Studies examining flow theory generally found higher levels of flow and immersion in gamified activities (Khoshnoodifar et al., 2023; Lozano et al., 2024; Marinho et al., 2025).

Most studies using the ARCS model reported increases across all four dimensions, Attention, Relevance, Confidence, and Satisfaction (Chen et al., 2023; Jiménez-Hernández et al., 2020; Zabala-Vargas et al., 2019, 2021), with particularly high attention scores in one case (Hernandez-Mena et al., 2024).

Although engagement was assessed less frequently, findings were generally positive. Higher engagement levels were observed following gamification (Boom-Cárcamo et al., 2024), including active participation in tasks (Feroz et al., 2020) and strong cognitive and emotional engagement (Santos-Guevara et al., 2024). Students also reported greater intentions to engage when they felt motivated (Aljamaan et al., 2025). Still, some limitations emerged: lower engagement was reported among low-performing students, such as those ranked poorly or failing

Table 1 Summary of the effects of gamification on student motivation and engagement in mathematics

Author	Year	Sample	Education level	Motivation/Engagement Theory	Effects
Aljamaan et al	2025	145	Higher Education	Motivation (Unidimensional)/Engagement	Positive
Ariffin et al	2022	111	Higher Education	Motivation (Unidimensional)	Positive
Boom-Cárcamo et al	2024	79	Higher Education	Motivation (Unidimensional)/Engagement	Positive
Celis et al	2023	187	Higher Education	Motivation (Unidimensional)	Positive
Chen et al	2018	80	Higher Education	Engagement	Neutral
Chen et al	2023	36	Secondary Education	ARCS/Flow	Positive
Dicheva et al	2021	40	Higher Education	SDT	Neutral
Feroz et al	2020	72	Higher Education	Engagement	Positive
Fuentes-Cabrera et al	2020	62	Secondary Education	Motivation (Unidimensional)	Positive
Fuentes-Riffo et al	2023	89	Secondary Education	SDT	Positive
García-Hernández and González-Ramírez	2021	178	Higher Education	SCT	Positive
García-López et al	2023	63	Higher Education	SDT/SCT	Negative
Hammad et al	2022	130	Higher Education	Motivation (Unidimensional)/SDT/SCT	Positive
Hazan et al	2018	99	Higher Education	SDT	Positive
Hernandez-Mena et al	2024	87	Higher Education	ARCS	Positive
Jiménez-Hernández et al	2020	62	Higher Education	ARCS	Positive
Khalid and Zainuddin	2020	34	Higher Education	SDT	Positive
Khoshnoodifar et al	2023	64	Higher Education	Flow	Positive
Kickmeier-Rust and Niggli	2023	43	Secondary Education	SDT	Positive
Lee et al	2023	218	Higher Education	Engagement	Negative
Lozano et al	2024	12	Secondary Education	Flow	Positive
Marinho et al	2025	127	Secondary Education	Flow	Positive
Mcintyre	2023	44	Higher Education	SCT	Positive
Montero-Izquierdo et al	2024	54	Higher Education	SCT	Positive

Table 1 (continued)

Author	Year	Sample	Education level	Motivation/Engagement Theory	Effects
Moral-Sánchez et al	2022	58	Secondary Education	Motivation (Unidimensional)	Positive
Neugebauer et al	2023	115	Higher Education	Motivation (Unidimensional)	Positive
Ooge et al	2024	127	Secondary Education	SDT	Positive
Ortiz-Rojas et al	2025	175	Higher Education	SDT/SCT	Neutral
Pais and Hall	2021	32	Higher Education	Motivation (Unidimensional)	Positive
Pedersen et al	2016	117	Secondary Education	SDT	Neutral
Pimentel et al	2022	29	Higher Education	Engagement	Positive
Reyssier et al	2022	258	Secondary Education	SDT	Negative
Rincon-Flores et al	2023	454	Secondary Education	Motivation (Unidimensional)	Neutral
Rincon-Flores et al	2022	78	Higher Education	Motivation (Unidimensional)	Positive
Robinson et al	2023	84	Higher Education	SDT/SCT	Positive
Saleh Alabdulaziz	2023	80	Secondary Education	Motivation (Unidimensional)	Positive
Sánchez González	2023	120	Secondary Education	Motivation (Unidimensional)	Positive
Santos et al	2021	30	Higher Education	Motivation (Unidimensional)	Positive
Santos-Guevara et al	2024	20	Higher Education	Engagement/ARCS	Positive
Stoyanova et al	2018	93	Secondary Education	SCT	Neutral
Vandercruysse et al	2015	98	Secondary Education	SDT/AGT	Negative
Wang et al	2024	71	Secondary Education	Motivation (Unidimensional)/Engagement	Positive
Zabala-Vargas et al	2021	106	Higher Education	ARCS	Positive
Zabala-Vargas et al	2019	19	Higher Education	ARCS	Positive
Zapata et al	2024	65	Secondary Education	Motivation (Unidimensional)	Positive

to earn badges (Lee et al., 2023), and one study found no significant differences in engagement between gamified and traditional groups (Chen et al., 2018).

Overall, the majority of the 45 studies included in this review reported positive effects of gamification on motivation and engagement in mathematics. Only four studies reported negative effects, relating to intrinsic/extrinsic motivation (Reyssier et al., 2022; Vandercruysse et al., 2015), self-efficacy (García-López et al., 2023), or engagement (Lee et al., 2023). Two of these studies were conducted in secondary education and two in higher education, with negative outcomes observed in general mathematics ($n=2$), calculus ($n=1$), and algebra ($n=1$).

Because engagement measures could not be synthesized meta-analytically, given the absence of validated instruments and the lack of studies with experimental-control comparisons, the reported outcomes were organized into behavioral, emotional, and cognitive engagement, following multidimensional frameworks (Fredricks et al., 2004). Table 2 summarizes these indicators and their theoretical categorization and shows that behavioral ($n=6$) and emotional ($n=4$) are the most frequent.

Table 2 Engagement outcomes, dimensions, and theoretical alignment in the included studies

Study	Measurement type	Reported indicators	Engagement category (Theoretical alignment)
Aljamaan et al. (2025)	Ad hoc scale	Behavioral engagement linked to motivation	Behavioral
Boom-Cárcamo et al. (2024)	Ad hoc scale and interviews	Learning feels more enjoyable and engaging (positive emotions)	Emotional
Chen et al. (2018)	Ad hoc scale	Perceived engagement (interaction; participation)	Behavioral & Cognitive
Feroz et al. (2020)	Student Course Engagement Questionnaire (SCEQ) (Handelsman et al., 2005) and observation	High participation; enthusiasm for sessions; students requested more *Kahoot!* activities	Behavioral & Emotional
Lee et al. (2023)	Observation and ad hoc scale	Participation and interest (some students lost interest due to competition); negative emotions (anxiety)	Emotional & Behavioral
Pimentel et al. (2022)	Student Course Engagement Questionnaire (SCEQ) (adapted from Rahman et al., 2018)	Skill engagement, interaction engagement	Behavioral & Cognitive
Santos-Guevara et al. (2024)	MAKE (Haruna et al., 2019) and interviews	Increased concentration and effort. Decrease of negative emotions (e.g., annoyance; shame)	Emotional & Cognitive
Wang et al. (2024)	Ad hoc scale	Increased learning engagement (participation)	Behavioral

Meta-Analysis

To account for potential correlations among 29 effect sizes within studies (k = 11), a CHE-RVE model was fitted with a CR2 small-sample adjustment. The estimated effect of gamification on students' motivation was statistically significant, yielding a moderate effect of *(g*=.383, *SE*=.140, 95% CI [.11,.66], *df*=9.41, *p*=.0218*)*. This comparison involved gamified groups (n = 1262) with traditional method groups (n = 1013) in the context of learning mathematics in secondary and higher education. The forest plot below (Fig. 4) displays individual effect sizes modeled using a three-level structure, with effect sizes nested within studies.

Heterogeneity and Moderators

The three-level CHE model indicated substantial heterogeneity. Variance decomposition showed that 31.56% of the total variance was attributable to between-study differences (Level 3), whereas 49.18% reflected within-study heterogeneity (Level 2) arising from multiple correlated outcomes reported within the same studies. The overall I^2 was 80.74%, indicating that most of the observed variability cannot be

Forest Plot of the estimated effects in the included studies

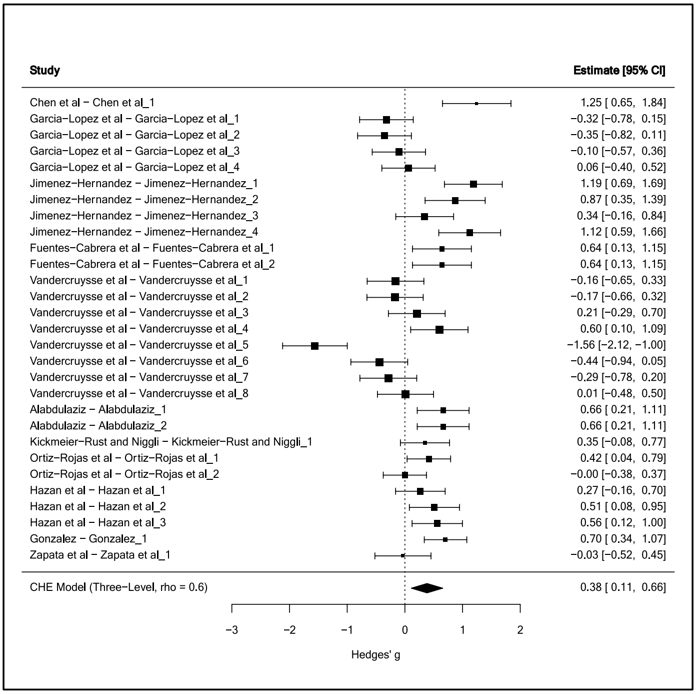

Fig. 4 Forest Plot of the estimated effects in the included studies

attributed to sampling error alone. This pattern provides clear justification for using a multilevel random-effects framework and supports the examination of potential moderators to explain part of this variability.

Three moderators were tested using the CHE model with RVE (CR2-adjusted standard errors): educational level, methodological quality (MMAT), and the presence of competitive elements. None explained a significant proportion of between-effect variation. Educational level did not differentiate effect sizes between secondary ($n=6$) and higher education ($n=5$) studies, with a nonsignificant contrast term ($\beta=0.10$, $SE=0.30$, $t(7.08)=0.33$, $p=.751$). The intercept representing higher education studies was also nonsignificant ($\beta=0.33$, $SE=0.23$, $p=.240$). Methodological quality, treated as a continuous predictor, was not associated with effect sizes ($\beta=-0.0128$, $SE=0.0124$, $t(3.65)=-1.04$, $p=.364$). Finally, gamification type (competitive vs non-competitive), coded based on explicit references to leaderboards, ranking systems, or social comparison mechanisms, did not moderate the effects ($\beta=0.02$, $SE=0.31$, $t(7.89)=0.05$, $p=.959$). The intercept for competitive designs showed a moderate effect ($\beta=0.38$, $SE=0.17$), although it did not reach statistical significance ($p=.081$). These findings suggest that, despite the substantial heterogeneity observed in the overall model, the moderators examined did not account for additional between-effect variation.

Sensitivity Analysis

Several sensitivity analyses were conducted to assess the robustness of the findings. First, varying the assumed within-study correlation ($\rho=0.30$, 0.60, 0.90) produced similar estimates (Table 3), indicating that the results are stable across different dependence assumptions. Second, to examine the influence of methodological quality, we excluded the lower-quality studies. As no study scored below 50% on the MMAT, the next meaningful threshold (MMAT ≤ 60%) was applied. Removing these studies yielded a less precise but statistically consistent estimate ($g=0.107$, 95% *CI* [- 0.368, 0.581]) relative to the main model, with substantial overlap in confidence intervals. Additionally, two alternative model specifications were examined: a random-effects model using a single aggregated effect per study ($g=0.416$, 95% *CI* [0.160, 0.672]) and a model restricted to peer-reviewed studies ($g=0.364$, 95% *CI* [- 0.009, 0.736]), both were closely aligned with the primary CHE–RVE estimate. Taken together, these analyses support the robustness of the findings across quality thresholds, dependence assumptions, publication types, and alternative modelling strategies.

Table 3 Sensitivity analysis

ρ	*g*	*SE*	*p(Satt)*
0.3	0.384	0.14	0.022
0.6 (default)	0.383	0.14	0.021
0.9	0.383	0.13	0.021

ρ Assumed within-study correlation used in the imputed covariance matrix (CHE-RVE), *g* Hedges' g, *SE* Standard error, *p* (Satt) *p*-value based on Satterthwaite-adjusted degrees of freedom

Model Comparison

To evaluate whether modeling between-study heterogeneity improved fit, a likelihood-ratio test (LRT) compared the full three-level model with a reduced model constraining between-study variance to zero. The full model yielded slightly better indices (AIC = 46.58 vs. 47.24; BIC = 50.58 vs. 49.91), but the improvement in log-likelihood was not significant (LRT = 2.66, $p = 0.103$). However, as the estimated between-study variance was non-negligible ($\sigma^2_3 = 0.093$) and the full model accounted for effect size dependence, it was retained for subsequent analyses.

Influence Analysis

An influence analysis was conducted to identify outliers and influential cases. One effect size from Vandercruysse et al. (2015) emerged as an outlier ($g = -1.56$, 95% *CI* [−2.12, −1.00]), but diagnostics indicated minimal impact on the overall model (Cook's Distance = 0.011; DFBETAS = −0.11; Hat Value = 0.010). As all values were below conventional thresholds, the effect was retained in the final analysis.

Publication Bias

To consider the presence of publication bias, multiple approaches were used. A funnel plot based on aggregated data per study appeared symmetric, although some dispersion was noted among studies (Fig. 5).

Then, to assess small-study effects, we conducted an Egger's regression with RVE, with the standard error (sqrt(vi)) as a moderator and clustering by study. The regression intercept was non-significant ($b = .767$, $SE = 1.98$, t (4.71) = .39, $p = .715$), and the slope was also non-significant ($b = -1.597$, $SE = 8.78$, t (4.65) = -.18, $p = .863$). These results suggest no evidence of funnel plot asymmetry or small-study effects. Additionally, a PET-PEESE analysis was performed using the same robust estimation approach. Both models yielded non-significant intercepts ($p = .715$ and $p = .585$, respectively), suggesting no clear evidence of small-study effects or publication bias.

Discussion

The present study examined the effects of gamification on students' motivation and engagement in mathematics education at the secondary and higher education levels through a systematic review and meta-analysis. Across 45 studies with 4,345 participants, most interventions targeted core mathematical topics such as algebra, calculus, statistics and used quasi-experimental designs. Game elements most frequently implemented were points, leaderboards, and rewards,

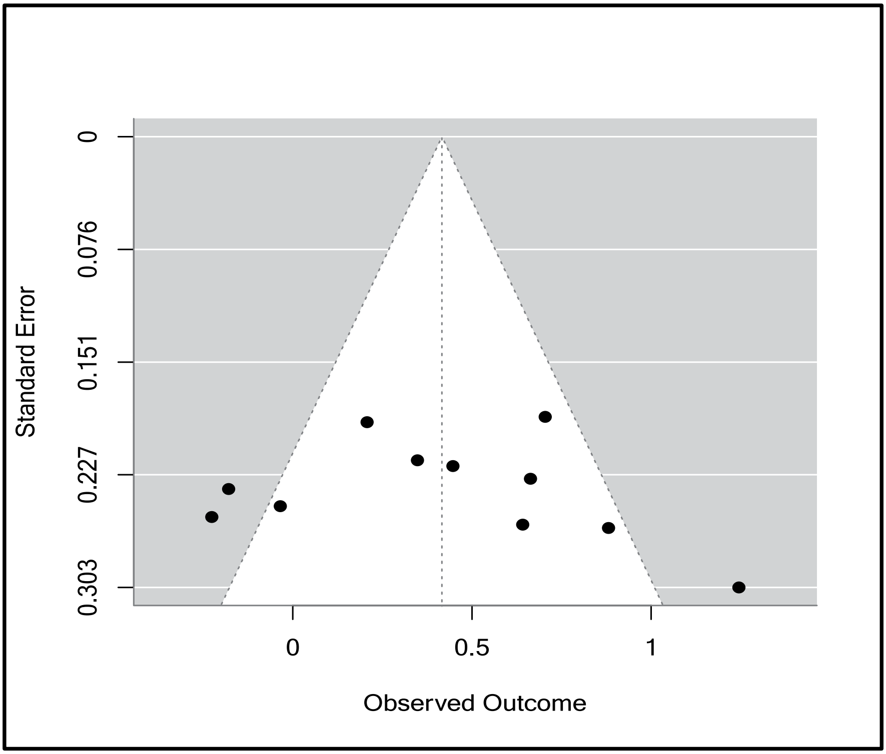

Fig. 5 Funnel Plot with aggregated effects

often through platforms such as *Kahoot!* (Feroz et al., 2020; Stoyanova et al., 2018), reflecting trends in the wider gamification literature (Huang et al., 2020; Manzano-León et al., 2021).

Regarding theoretical grounding, motivation was predominantly examined through SDT, followed by SCT and the ARCS model, confirming SDT's role as the dominant framework (Alsawaier, 2018; Ratinho & Martins, 2023). This highlights the centrality of autonomy, competence, and relatedness in explaining gamification's effects, but also the need to diversify theoretical approaches. Engagement, in contrast, remains underexplored, as most studies relied on indirect measures or ad hoc instruments rather than validated instruments. This pattern is consistent with previous literature (Alsawaier, 2018; Dichev & Dicheva, 2017).

The meta-analysis of eleven studies revealed a small-to-moderate positive effect on motivation ($g=0.383$), consistent with previous meta-analyses in general education contexts (Li et al., 2024; Sailer & Homner, 2020). This indicates that gamification has meaningful potential in mathematics, where motivation is often difficult to sustain. To examine sources of variability, three study-level moderators were tested: educational level, competitiveness of the design and methodological quality. None significantly predicted effect sizes, indicating that the substantial heterogeneity observed cannot be explained by these broad characteristics. Additional heterogeneity likely stems from others factors such as implementation fidelity (i.e. duration; intensity), variation in mathematical content, measurement inconsistencies and differences in design. Collectively, this suggests that variability in gamification outcomes reflects practical and contextual design differences.

Not all results were positive. Some studies found that difficult-to-obtain badges or persistent low leaderboard rankings reduced engagement (Lee et al., 2023), poorly adapted designs lowered self-efficacy (García-López et al., 2023), or competitive elements increased amotivation among already motivated learners (Reyssier et al., 2022). External rewards such as cinema tickets or grade points also proved insufficient to sustain motivation (Vandercruysse et al., 2015). Neutral results were also observed, such as rewards failing to motivate all students (Rincon-Flores et al., 2023), *Kahoot!* not uniformly enhancing intrinsic motivation (Stoyanova et al., 2018), or leaderboards boosting motivation for some while reducing autonomy for others (Ortiz-Rojas et al., 2025). These patterns are consistent with SDT: controlling or comparative elements may undermine autonomy and competence, whereas designs that provide immediate feedback, scaffolding and opportunities for self-paced progression tend to support basic psychological needs (Deci & Ryan, 2000; Reeve, 2012; Ryan & Deci, 2017).

Across the studies assessing engagement, most reported gains in engagement. Interventions that combined gamification with interactive or narrative structures tended to increase participation and attention (Feroz et al., 2020; Pimentel et al., 2022; Wang et al., 2024). Boom-Cárcamo et al. (2024) similarly observed increased collaboration and persistence during mathematical problem-solving. In contrast, Chen et al. (2018) found higher participation but no meaningful change in perceived engagement, while Lee et al. (2023) reported reduced engagement among lower-performing students exposed to competitive or performance-oriented mechanics. In general, engagement improved when gamification supported students' autonomy, competence, and enjoyment, whereas highly competitive or performance-oriented designs tended to reduce engagement. These findings are consistent with evidence that motivation and engagement operate in close reciprocal relation (Reeve, 2024).

Importantly, current evidence does not suggest that gamification functions differently in mathematics compared with other subjects. Reviews such as Zeybek and Saygı (2023) report similar motivational benefits and similar risks of neutral or negative effects across disciplines. Thus, the effectiveness of gamification seems less dependent on domain and more on implementation quality.

Taken together, the findings indicate that gamification can meaningfully enhance motivation and engagement in mathematics when aligned with students' needs and preferences. Poorly aligned or overly competitive designs may undermine these same needs. The central question is therefore not whether gamification works, but for whom, under what conditions, and through which design choices it is most effective.

Practical and Theoretical Implications

This review suggests that gamification can enhance students' motivation in mathematics, although its effectiveness appears to depend on design features. Game elements such as points, badges and leaderboards are unlikely to be effective when added superficially; rather, evidence support that their effectiveness depends on alignment with students' psychological needs. Such designs can create conditions for an optimal challenge, balancing task difficulty to maintain engagement and promote a sense of competence and mastery (Csikszentmihalyi, 1990; Deci & Ryan, 2000; Ryan & Deci, 2017). Competitive features can be motivating, but if overemphasized, they risk discouraging less competitive students. Available evidence point that mastery-oriented structures, gradual progression through increasing levels of difficulty and the use of individual progress indicators may be more effective for sustaining motivation (see Table 4). Similarly, cooperative mechanics appear beneficial, as they foster relatedness while balancing competition (García-López et al., 2023; Lee et al., 2023; Reyssier et al., 2022; Vandercruysse et al., 2015). Widely used platforms such as *Kahoot!* can provide practical entry points for teachers but rely on competition, which requires careful balance. In terms of effectiveness, external rewards appear to require careful use and are more likely to be beneficial when complemented by support for autonomy, competence, and relatedness, such as meaningful feedback, opportunities for self-paced learning and collaboration (Reeve, 2024). In this sense, badges, for example, can serve not merely as extrinsic reinforcers but as informative feedback, signaling progress or mastery rather than control, thereby reinforcing competence and internal motivation (Deci & Ryan, 2000; Reeve, 2012; Ryan & Deci, 2017).

The findings support the central role of SDT while showing the value of integrating complementary perspectives such as the ARCS model, AGT, SCT and Flow Theory, which capture motivational processes not fully addressed by SDT alone. A recurring limitation in the field is the reliance on non-validated or ad hoc measures of motivation, often with limited theoretical grounding, which simplifies the construct and restricts comparability across studies. Similarly, the absence of validated engagement measures constitutes a substantive theoretical gap and limits the ability to examine how motivation and engagement operate together in gamified learning.

Because most studies were conducted in Western higher-education settings, it is unclear whether these findings generalize to more culturally diverse classrooms. Perceptions of competition, autonomy and failure can differ across cultural and demographic groups, implying that gamification may require cultural adaptation, gender-sensitive adjustments or consideration of sociodemographic factors (e.g., socioeconomic conditions) to ensure equitable benefits (Asrifan et al., 2025). Addressing these differences could strengthen theoretical models and support more inclusive design principles (Oliveira et al., 2023). Recent work on player typologies (e.g., the HEXAD model) offers validated tools to identify motivational preferences (dos Santos et al., 2025). Incorporating such instruments into design and evaluation might help tailor gamification to learner characteristics, better aligning game mechanics with motivational and engagement needs and reducing mismatches

Table 4 Gamification elements according to learner characteristics

Game Element	Possibly effective for	Possibly less effective for	Examples
Avatar	Learners with high initial amotivation. May support engagement and identification (autonomy; self-efficacy)	No evidence of avoidance profiles in this review	Rincon-Flores et al. (2023); Santos-Guevara et al. (2024)
Badges	Learners low in intrinsic motivation/Extrinsic motivators	Learners initially high in intrinsic motivation (can be perceived as controlling)	Lee et al. (2023); Reyssier et al. (2022); Moral-Sanchez et al. (2022)
Progress/Levels	Learners with high initial amotivation. May promote extrinsic motivation	Intrinsic motivation (could be perceived as controlling, increase anxiety, or reduce autonomy)	Chen et al. (2023); Fuentes-Riffo et al. (2023); Montero-Izquierdo et al. (2024); Reyssier et al. (2022)
Ranking/Leaderboards	Learners high in extrinsic motivation (competition may be experienced as challenging)	Learners high in intrinsic motivation (may reduce autonomy and competence)	Lee et al. (2023); Reyssier et al. (2022); Vandercruysse et al. (2015)
Collaborative rankings/ Team tasks	Social learners and learners with high initial amotivation; Intrinsic motivators	Can be demotivating to individual competitors (extrinsic motivators)	García-López et al. (2023); Marinho et al. (2025)
Score/Points	High initial intrinsic motivation (may support perceived competence)	Learners with high extrinsic motivation, high amotivation (could be perceived as controlling)	Celis et al. (2023); Lozano et al. (2024)
Timer/Time Pressure	Learners with high initial amotivation; extrinsic motivation students	Learners high in intrinsic motivation (may increase anxiety or undermine autonomy)	Lee et al. (2023); Reyssier et al. (2022); Saleh Alabdulaziz (2023)
Rewards	Learners with high extrinsic motivation	Learners high in intrinsic motivation (may increase extrinsic motivation behaviors)	Robinson et al. (2023); Vandercruysse et al. (2015); Zabala Vargas et al. (2019)

between design features and student dispositions (Hong et al., 2024). Collectively, these cultural and individual differences suggest the need to move beyond uniform, one-size-fits-all approaches toward adaptive systems in which game elements align with learners' motivational profiles, individual differences and the sociocultural characteristics of the classroom.

Limitations and Future Studies

This review has several limitations. Some included studies (e.g., conference papers, book chapters) may not have undergone full peer review. The MMAT appraisal did not reveal clear differences in methodological quality between peer-reviewed and non-peer-reviewed sources; however, this finding should be interpreted cautiously. The limited number of studies, together with substantial heterogeneity in study designs and reporting practices, prevents strong conclusions regarding comparative methodological quality across publication types. The meta-analysis was based on a relatively small set of 11 studies, several of which used heterogeneous or non-validated instruments, limiting the stability of effect-size estimates. The small number of eligible studies also restricted the moderator analyses: only simple, single-moderator models could be estimated, and these results should be interpreted cautiously due to limited statistical power. Engagement was rarely measured using validated tools and comparing an experimental group to a control group, preventing a meta-analytic synthesis of this construct.

Future research should employ more rigorous designs, validated measures, and larger samples, and should expand the evidence base to primary education. Also, future reviews should include academic achievement alongside motivation and engagement. In addition, culturally diverse settings and underrepresented groups require greater attention to ensure equitable and contextually sensitive gamification designs.

Conclusion

This systematic review and meta-analysis examined the effects of gamification on students´ motivation and engagement in mathematics education at the secondary and higher education levels. Across the 45 included studies, gamified strategies were often associated with improvements in students´ motivation and engagement, although a small number of studies ($n = 4$) reported negative effects. These negative outcomes were primarily reported in contexts involving competition and social comparison, the use of external rewards, and poorly designed gamified strategies that were not adapted to students' characteristics. Based on 11 studies, the meta-analytic CHE model using RVE indicated a statistically significant positive effect of gamification on motivation ($g = 0.383$), representing a small to moderate increase in motivational outcomes for students exposed to gamified mathematics instruction. However, substantial heterogeneity was observed across studies, and limited data were available to assess engagement effects. Most studies relied on non-validated (e.g., ad hoc surveys) or indirect measures of engagement, which prevented its inclusion in the quantitative synthesis. Taken together, the limited exploration of engagement and the overall quality of existing studies suggest that, while gamification appears to be a promising approach for enhancing motivation and engagement in mathematics education, the field remains at a developmental stage.

Appendix 1

Table 5 Database-specific search strings

Database	Search strategy
Web of science core collection	TS = ((("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "secondary level" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction")))
Scopus	TITLE-ABS-KEY (("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "secondary level" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction")) AND NOT ("primary school" OR "elementary school" OR "preschool")
IEEE XPLORE	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "secondary level" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction")) NOT ("primary school" OR "elementary school" OR "preschool")

Table 5 (continued)

Database	Search strategy
ERIC	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")
APA PsycInfo	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR “game mechanics” OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "secondary level" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR “master's degree” OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")
MathSciNet	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")

Table 5 (continued)

Database	Search strategy
Arxiv	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")
ZentralBlatt MATH	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")
Psychology and behavioral sciences collection	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")

Table 5 (continued)

Database	Search strategy
Jstor	("gamification" OR "gameful" OR "gamified" OR "game elements" OR "ludic design" OR "game design" OR "game mechanics" OR "serious games" OR "game-based learning" OR "educational games") AND ("high school" OR "secondary school" OR "higher education" OR "college" OR "university" OR "junior high" OR "secondary education" OR "undergraduate" OR "tertiary education" OR "academic institutions" OR "degree programs" OR "doctoral programs" OR "bachelor's degree" OR "master's degree" OR "academic degree") AND ("mathematic*" OR "geometry" OR "algebra" OR "statistics" OR "calculus" OR "probability" OR "trigonometry" OR "arithmetic" OR "math" OR "number theory" OR "numeracy" OR "STEM education" OR "mathematics learning" OR "math education" OR "math instruction" OR "mathematics teaching" OR "mathematical literacy") AND ("motiv*" OR "self-determination" OR "arcs model" OR "goal setting theory" OR "self-regulation" OR "self-efficacy" OR "regulation" OR "engag*" OR "flow theory" OR "involvement" OR "commitment" OR "participat*" OR "interaction") NOT ("primary school" OR "elementary school" OR "preschool")

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Declarations

Conflict of interest The authors disclose that they have no actual or perceived conflicts of interest.

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