Volume 10 Number 3, December 2025, pp. 524~535
P-ISSN:2477-7935
E-ISSN: 2548-6225
DOI: 10.59052/edufisika.v10i3.47980

TRENDS AND INSIGHTS OF GAMIFICATION IN LEARNING FOR SCIENCE EDUCATION: A SYSTEMATIC LITERATURE REVIEW

Alfiani Syarifatul Ajri[1], Insih Wilujeng [2], dan Heru Kuswanto [3]
[1,3] Physics Education, Universitas Negeri Yogyakarta, Daerah Istimewa Yogyakarta, Indonesia
[2] Science Education, Universitas Negeri Yogyakarta, Daerah Istimewa Yogyakarta, Indonesia
Corresponding author email: alfianisyarifatul.2024@student.uny.ac.id

Article Info
Received: 24 August 2025
Accepted: 15 December 2025
Publication: 25 December 2025

Abstract :
Gamification is increasingly used in education. There are 20 articles on games in learning that highlight the importance of identifying game characteristics and their potential for science learning at the senior high school level. The data is sourced from publications indexed on Scopus from 2017 to 2024. Data collection used the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) method. The identification stage yielded 554 articles from Scopus. After screening, 50 articles met the criteria, and 20 final articles were analyzed in depth. The findings indicate that gamification has extensively incorporated both technology and traditional games. Trends in research reveal a significant focus on gamified products in chemistry, particularly for facilitating the comprehension of abstract concepts. Additionally, literature underscores the effectiveness of games as tools for enhancing learning and supporting material review. Research has shown that gamification in learning enhances various skills, such as learning outcomes, motivation, conceptual understanding, critical thinking, and mathematical representation. However, its influence on skills like collaboration, anxiety reduction, retention, cognitive abilities, academic performance, self-efficacy, and science literacy presents an area for further exploration. This study recommends that teachers apply digital gamification for abstract concepts and develop board games for collaborative contexts. Future research should expand gamification studies to physics and biology.

Keywords: Gamification, Science Education, Literature Review

INTRODUCTION

Game-based learning is increasingly used in education. It is becoming a new trend gaining popularity along with the development of digital technology (Al-Hafdi & Alhalafawy, 2024). Teachers need to utilize ICT, mobile learning, and games to enhance engagement in learning (Yunus & Zaibon, 2021). The application of game elements in education is possible in supporting various objectives for educational development (Martins et al., 2024). Gamification offers an alternative pathway to make the concept of science more concrete, interactive, and engaging.

The use of gamification provides benefits at the high school level. In high school, learning does not focus solely on the transfer of knowledge (Fauziah & Sulisworo, 2022). The incorporation of gamification aims to provide a more interesting, attractive, and effective learning experience for students (Katanosaka et al., 2023; Silva et al., 2022; Yunus & Zaibon, 2021). It provides teachers with tools to increase engagement, motivation, and learning (Saxena & Mishra, 2021). This active engagement not only reinforces learning but also makes the educational process more enjoyable, thus increasing long-term retention (Riquelme et al., 2024). Students actively engage with information proactively rather than just taking it in (Richter & Kickmeier-Rust, 2025). Thus, gamification has been proven to be effective in improving students' long-term knowledge retention through enjoyable learning experiences.

The research literature found that elements of gamification influence students' skills. Leaderboard design can have a beneficial influence on students' learning motivation, engagement, and performance (Li et al., 2024). Points and badges are used to motivate students in learning and learning outcomes as a form of direct feedback on student behavior or performance (Meng et al., 2024). Games are associated with fun, engagement, and competitiveness, and present opportunities for social interaction and self-expression in a non-threatening environment (Yunus & Zaibon, 2021).

Empirical studies have been conducted extensively on gamification in learning. According to Riquelme et al. (2024), games promote active participation, independence, and group collaboration. However, Meng et al. (2024) discovered that the use of games in learning is not the major method for addressing challenges with complex students. The badge element is unrelated to skills, emotions, or performance. Riquelme et al. (2024) adds that there are disadvantages to the rigidity of game evaluation systems. Most of the research on using games to promote learning has been conducted in schools, universities, and healthcare settings.

A review of gamification has been conducted in the literature analysis (Alahmari et al., 2023; Kalogiannakis et al., 2021). However, limited attention has been given to its application at the high school level. This study aims to fill this gap by analyzing literature from 2017 to 2024, thereby offering an updated perspective on how gamification is implemented and evaluated in high school science learning.

The distinction between gamification and game-based learning is essential because each approach relies on different implementation mechanisms. Christopoulos & Mystakidis (2023) states that gamification refers to the application of game-design elements and principles in a non-game context. Pavey (2021) adds that these elements function to enhance students' motivation and engagement in learning. In addition, game-based learning is defined as an enjoyable instructional model that employs games as the primary medium for achieving predetermined learning objectives (Atoulloh et al., 2024; Pavey, 2021).

This study aims to describe characteristics of games and their potential in science learning at the high school level. The research questions for this study focus on the description of access to learning with games, trends in the application of gamification in science subjects in high school, and the impact of gamification on students' skills. The findings of this research provide valuable insights to support teachers in selecting game-based approaches that enhance both conceptual understanding and skill development.

RESEARCH METHOD

Research Design

This study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. A systematic review approach was adopted, which involves identifying, evaluating, and interpreting all research findings relevant to the research question, topic, or phenomenon of interest (Nasiroh et al., 2025). The systematic literature review process comprised three stages: identification, screening, and inclusion.

This study is a literature review, and therefore, the research subjects are scientific articles. Articles selected from Scopus-indexed journals with a focus on publications from 2017 to 2024. The final sample consists of 20 selected articles that met the specific inclusion and exclusion criteria established for this research.

Research Procedure

At the identification stage, an initial search was conducted in the database using specified queries. A Boolean query was constructed to filter studies discussing gamification at the high school level. The keyword combinations used in this research are ("gamification" OR "gamification physics" , OR "gamified application" , OR "applied game design" , OR "Game") AND ("scientific education" OR "science teaching" OR "teaching of science" , OR "science education" OR "chemistry" OR "geology" , OR "physics" OR "biology" OR "astronomy" OR "natural sciences" OR "earth sciences") AND ("high school" OR "senior high school" OR "Grade 10" OR "Grade 11" OR "Grade 12"). The search retrieved 554 records from Scopus. As the search was conducted within a single database, duplicate records were not detected, and thus no removal was required. The research procedure is described in Figure 1.

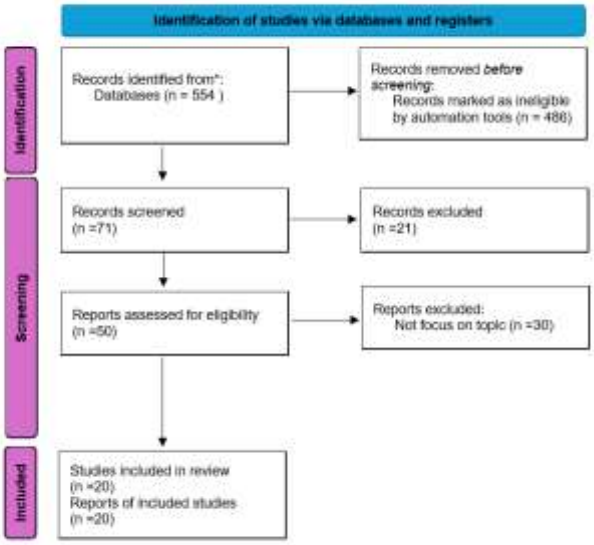

Figure 1. Research steps of reviewing literature

The screening stage was based on several criteria to ensure the relevance and quality of the selected studies. The inclusion criteria focused on scope, accessibility, and publication standards, while the exclusion criteria excluded studies that did not align with the research focus. Table 1 presents the inclusion and exclusion criteria used in this study.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Literature in the form of scientific journals	Articles with overly general discussions
Scopus-indexed journals	Non-Scopus
Social science subject area	Non–open access
Final publication stage	Not written in English
Open access journals	Published before 2017 or after 2024
Full-text accessible	
Written in English	
Publication years 2017–2024	
The discussion in scientific journals concerns games in science learning at the senior high school level.	

This restriction was applied because Scopus classifies education within the broader social sciences subject area. This study did not limit the type of documents for screening. Based on these inclusion criteria, 71 articles remained. The titles and abstracts of 71 articles were screened for relevance to high school science education and games. At this stage, 21 articles were excluded due to overly general discussions, leaving 50 potentially relevant studies.

In the inclusion stage, the full texts of the 50 remaining articles were carefully reviewed and analyzed in detail. Thirty articles were excluded at this stage because they did not align well with the specific research question. Consequently, 20 articles were retained for the final dataset and analyzed.

Instruments and Data Collection Techniques

The data collection process in this study was conducted in three main stages in accordance with PRISMA guidelines. The first stage, identification, entailed retrieving articles from relevant databases. The source database employed for the literature search was Scopus. This study selected the Scopus database because it provides extensive coverage and offers greater accessibility compared to other databases (Giang et al., 2025; Karakose et al., 2022). Data collection was performed using a systematic literature search conducted in October 2024. In the screening stage, the retrieved records were examined based on predetermined inclusion and exclusion criteria. Finally, at the inclusion stages, articles that did not satisfy the criteria were excluded, resulting in the final set of studies for analysis.

Data Analysis Technique

The data analysis involved a thorough reading of the 20 selected articles. Information from each article was extracted and interpreted to identify gamification implementation, key outcomes, the subject matter applied in the research, and access used in learning related to the study's primary objectives. This process allowed for a comprehensive understanding of the current state of research on gamification in high school science education. A content analysis was employed to categorize the extracted information. Each article was reviewed based on concepts relevant to the research objectives. The extracted data was analyzed using qualitative techniques. The data was calculated using frequency counts and percentages, then visualized in tables and graphs to highlight publication trends.

RESULTS AND DISCUSSION

Gamification in learning has recently gained considerable traction in science education. Table 2 presents a summary of findings from relevant articles obtained through the PRISMA process. The number of articles that match the research question is 20. These articles were found in scientific publication databases such as Scopus.

Table 2. Articles' information

Author and Year	Country	Subject	Gamification Implementation	Key Outcomes
Lathwesen & Eilks (2024)	Germany	Chemistry (Green Chemistry)	Digital Educational Escape Room (EER). A game with a space mission narrative in which students must solve a series of puzzles to control the spaceship to fly back to Earth.	motivation, collaboration, and learning
da Silva Júnior et al. (2024)	Brazil	Chemistry (Thermo, Equilibrium, Kinetics)	Online Cooperative Game. This game is designed as a digital board game accessible online.	students' performances
Rizki et al. (2024)	Indonesia	Physics	CAP (Cooperative model, digital game, and Augmented Reality)	critical thinking skills and learning motivation
Hariyono et al. (2023)	Indonesia	Physics	The game of Engklek is used as an ethnoscience-based activity that facilitates the discovery process in the discovery learning model.	Conceptual understanding and learning Motivation
Hou et al. (2023)	Northern Taiwan	Chemistry (gas and pressure gauges)	game-based learning on board games with mobile devices to provide digital and real-time scaffolding	learning outcomes, anxiety, and behavior patterns

Author and Year	Country	Subject	Gamification Implementation	Key Outcomes
Montagnani et al. (2023)	Italy	Physics	learning through tournaments using a game called Quantum Tic-Tac-Toe (QTTT)	students' understanding
Lutfi et al. (2023)	Indonesia	Chemistry (hydrocarbon)	House of Chemistry is a 2D game about someone who must escape from a chemistry lab by overcoming various obstacles	student motivation and learning outcomes.
Lutfi et al. (2023)	Indonesia	Chemistry (hydrocarbon)	A game called Hydrocarbons Chem-Rush, developed as an adventure and endless run game.	learning outcomes and student motivation
Haimovich et al. (2022)	Israel	chemistry	Students participate in a digital game called Virtual Chemical Escape Room (VChEsRm) to solve mysteries using their chemistry knowledge.	motivation and problem solving, interpersonal communication, and teamwork
Villamor & Lapinid (2022)	Philippines	chemistry	The online platform used to manage class activities and outputs is Classcraft.	students' motivation and academic performance
Putranta et al. (2021)	Indonesia	Physics	learning that integrates traditional games (tulup, benthik, bekelan, sulamanda, egrang, sekongan, jeblugan, and gobak sodor) into physics learning.	Not specified. In this study, physics learning was more meaningful through the integration of traditional games.
Lutfi et al. (2021).	Indonesia	Chemistry (chemical bonding)	Implementation of a game called Chebo Collect, a 2D adventure investigation game.	student learning outcomes
Ika Rahayu & Kuswanto (2021).	Indonesia	Physics (momentum and impulse)	The implementation of Android-based carom game comics in learning	critical thinking and mathematical representation skills
Sari et al. (2020).	Indonesia	Physics (momentum and impulse)	Integration of the traditional game of hopscotch (engklek) into learning	mathematical representation and creative thinking skills
Fitriyana et al. (2020).	Indonesia	Chemistry (hydrocarbon)	The implementation of Android-based games in learning	self-efficacy and student achievement
Dziob (2020)	Poland	Physics (Waves and	The implementation of game boards as an assessment method	collaborative skills,

Author and Year	Country	Subject	Gamification Implementation	Key Outcomes
		vibrations, Optics)		performance, and short-term achievement
Rossi et al. (2020).	Italy	Chemistry (crystallography)	puzzles game	students' understanding
Bibic et al. (2019).	United Kingdom	Biology	game virtual reality (VR)	science literacy
da Silva Júnior et al. (2018)	Brazil	Chemistry (organic nomenclature)	An interactive game called "Say My Name" is a learning tool to review topics	engagement and learning outcomes
Cahyana et al. (2017).	Indonesia	Chemistry (Reaction Rate)	Mobile game-based learning is conducted through quizzes on Android phones.	learning outcomes

The studies analyzed in this research generally stand out in Asia and Europe, with contributions also beginning to emerge from other regions such as Latin America. This distribution pattern confirms that gamification in science education has developed as a cross-continental empirical research topic. This geographical variation also reflects that the implementation of gamification is developing in line with educational needs, technological readiness, and the local socio-cultural context in each country (Jayanta et al., 2025). Overall, this direction of development indicates a global trend towards active, technology-based, and learner-centered learning (Sitorus et al., 2025). Thus, gamification in science education can be seen as an innovation that transcends regional boundaries while adapting to local educational contexts. In accordance with this global trend, the distribution of access to learning with games is shown in Figure 2.

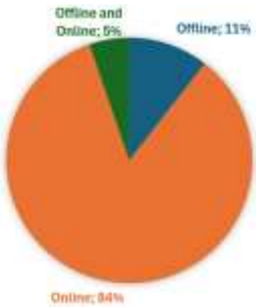

Figure 2. Access used in learning with games

Science learning with games can be presented offline, online, or in a mixed format. The review of the literature shows that access to learning through games is available online. Online learning conducted by other researchers using website media (Lathwesen & Eilks, 2024), application media that can be downloaded via mobile phones (Rizki et al., 2024), and comic media (Rahayu & Kuswanto, 2021). Some researchers name the games used, such as The Green Chemistry Escape Room: Space Mission." (Lathwesen & Eilks, 2024), House of Chemistry (Lutfi et al., 2023), Hydrocarbons Chem-Rush (Lutfi et al., 2023), Chebo Collect (Lutfi et al., 2021), Bug Off Pain (Bibic et al., 2019), dan Say My Name (da Silva Júnior et al., 2018). The tendency to use digital technology in gamification is because digital technology offers flexibility and interactivity that allows educators to design adaptive learning experiences (Kozub et al., 2024; Situmorang et al., 2024). Digital environments also support learning styles, which facilitates deeper cognitive processing of scientific concepts (Sasikala & Ravichandran, 2024; Suryanarayana et al., 2024).

Offline learning includes face-to-face learning activities between teachers and students. The analysis shows that games that can be done offline include board games (Dziob, 2020). Meanwhile, (Hou et al., 2023) mentioned that blended learning can be an alternative in science teaching. Blended learning combines mobile apps that can support the learning process. The distribution of implementation trends of gamification in science subjects in senior high schools is shown in Figure 3.

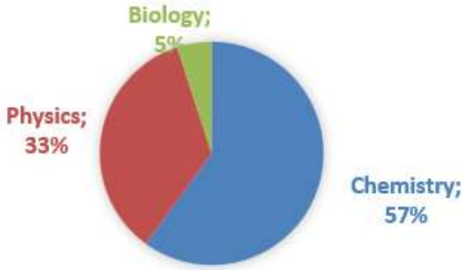

Figure 3. Implementation trends of gamification in science subjects

Among the 20 analyzed studies, chemistry dominates the use of games in science learning, followed by physics and biology. Concepts taught in learning with games include green chemistry materials (Lathwesen & Eilks, 2024), thermochemistry, kinetic chemistry, chemical equilibrium (da Silva Júnior et al., 2024), hydrocarbons (Fitriyana et al., 2020; Lutfi et al., 2023; Lutfi et al., 2023), atomic model, radioactivity, periodic table (Haimovich et al., 2022), chemical bonds (Lutfi et al., 2021), and nomenclature of organic chemistry (da Silva Júnior et al., 2018). Chemistry is more dominant because many of its concepts cannot be seen directly, so this method helps students visualize them. The physics concepts found include work, energy, equilibrium of rigid bodies, momentum, impulse (Sari et al., 2020), parabolic motion (Hariyono et al., 2023), quantum physics (Montagnani et al., 2023), waves, vibrations, and optics (Dziob, 2020), and crystal structure (Rossi et al., 2020). There are fewer studies in the field of physics because physics emphasizes quantitative reasoning, making it challenging to develop into a game without simplifying the concepts. Meanwhile, research on biological topics covered spider venom and sensory systems (Bibic et al., 2019).

Research on the use of games in chemistry learning is intensive. Alahmari et al. (2023) revealed that chemistry is one of the fields that is often researched in the context of educational games, with a percentage of 19.3%. One innovative product in this field is a flash card game, designed to address the topics of thermochemistry, chemical kinetics, and chemical equilibrium. (da Silva Júnior et al., 2024). The game is designed to be easy for students to play, making it a fun and interactive review tool.

The literature shows that games are effective for learning and a tool for reviewing material understanding. One example is a board game for the topic of chemical compound names developed by da Silva Júnior et al. (2018). The product contains questions of varying difficulty, which students can select by rolling a die. The level of questions allows students to answer according to their ability (Preston et al., 2020). This study found that the use of leaderboards motivates students to play many times. This approach not only makes learning more interesting but also trains students to face challenges gradually, thereby improving their critical thinking skills and their ability to adapt to the material.

Similar approaches were also found in other studies that varied the type of questions in board games. Dziob (2020) adding a variety of question types to evaluate students' understanding. In the approach, all questions required students to perform different activities and awarded different numbers of points. These findings suggest that variations in question types can increase student engagement and provide opportunities for future research to develop board games across various learning contexts. In addition to board games, various traditional games are also used for learning in physics.

Physics learning has integrated traditional games as a teaching context. One example of this is the Hopscotch comic product developed by Sari et al. (2020), which includes physics concepts, such as motion dynamics (parabolic motion and displacement), sound waves, equilibrium of a rigid body (center of gravity), and impulse and momentum. The product is packaged as an application that includes learning materials, learning videos, discussion sheets, sample experiment sheets, and practice exercises. In addition, the traditional game Engklek has also been used to teach physics concepts such as work and energy, rigid body equilibrium, momentum and impulse, and parabolic motion (Hariyono et al., 2023). In addition to traditional games, modern technology-based approaches are also starting to be applied in the learning of various science concepts.

Science learning with technology has been applied to facilitate the learning process. Montagnani et al. (2023) presents quantum topics through TiqTaqToe tournaments, thus creating playful activity. Rossi et al. (2020) conducted a puzzle game-based learning approach and tessellation technique to facilitate students' understanding of the difference between periodic and aperiodic 2D crystal structures. Bibic et al. (2019) applied game-based 3D VR to explain more realistically the biochemistry behind the venoms in relation to chronic pain. VR presentations can be modern-day teaching tools—demonstrating the impact of using learning with games on improving students' skills, as shown in Table 3.

Table 3. The Impact of utilizing learning with games on improving students' skills

Impact	References	Frequency	Percentage
Interest	(Lathwesen & Eilks, 2024; Lutfi et al., 2021)	2	10%
Motivation	(Hariyono et al., 2023; Lathwesen & Eilks, 2024; Lutfi, Aftinia, et al., 2023; Lutfi et al., 2023; Rizki et al., 2024; Villamor & Lapinid, 2022)	6	30%
Collaboration	(Lathwesen & Eilks, 2024)	1	5%
Concept understanding	(da Silva Júnior et al., 2024; Hariyono et al., 2023; Montagnani et al., 2023)	3	15%
Critical thinking skills	(Ika Rahayu & Kuswanto, 2021; Rizki et al., 2024; Sari et al., 2020)	3	15%
Learning outcomes	(Cahyana et al., 2017; da Silva Júnior et al., 2018; Dziob, 2020; Fitriyana et al., 2020; Hou et al., 2023; Lutfi, Aftinia, et al., 2023; Lutfi et al., 2021; Lutfi et al., 2023; Rossi et al., 2020)	9	45%
Anxiety	(Hou et al., 2023)	1	5%
Retention power	(Lutfi et al., 2023)	1	5%
Cognitive skills	(Haimovich et al., 2022)	1	5%
Academic performance	(Villamor & Lapinid, 2022)	1	5%
Mathematical representation	(Rahayu & Kuswanto, 2021; Sari et al., 2020)	2	10%
Self-efficacy	(Fitriyana et al., 2020)	1	5%
Science literacy	(Bibic et al., 2019)	1	5%

Table 3 shows that many skills are developed through learning with games, namely, student learning outcomes. The use of games during learning has a positive effect on students' understanding (Lutfi et al., 2023). Gupta & Goyal (2022) also stated that game-based pedagogical approaches yield better learning outcomes. Through games, students can learn flexibly by playing both inside and outside the classroom, and participate in face-to-face or remote settings that support cooperative and competitive learning modes (Cahyana et al., 2017; da Silva Júnior et al., 2024; Hariyono et al., 2023). These experiences increase motivation and engagement, which support deeper conceptual understanding (Oliveira et al., 2025). This finding reflects self-determination theory, which states that individuals achieve better learning outcomes when their needs for autonomy, competence, and relatedness are fulfilled (Ryan & Deci, 2000).

The impact of utilizing game learning on students' skills can be further explored. Aspects such as collaboration, anxiety, retention, cognitive skills, academic performance, self-efficacy, and science literacy are still rarely investigated. This scarcity may be due to the tendency of most studies to focus primarily on motivation and engagement, more directly linked to the design of gamified elements (Leitão et al., 2022). In contrast, skills such as collaboration or science literacy require more complex assessment instruments, longitudinal designs, or classroom-based observations, making them less frequently examined (Owens & Hite, 2022). Thus, existing gamification designs still emphasize individual competition rather than cooperative inquiry.

The challenge in implementing gamification in this literature review is to emphasize the teacher's active role. Teachers are expected to motivate collaboration among students, guide the learning process, and reflect and debrief with students on what they have observed (Haimovich et al., 2022). Teachers need to be creative in teaching science to students (Noor et al., 2022). In addition, the duration of gamification is often considered too short, requiring adjustments to the time and learning design for this method to work optimally (Saxena & Mishra, 2021). Thus, while gamification in learning has great potential, these challenges should be addressed through more in-depth empirical studies.

This study is subject to several limitations. First, the literature search was restricted to the Social Sciences subject area in Scopus. Consequently, relevant studies indexed in other subject areas or databases may not have been captured. This review focused on three main aspects: access to game-based learning, trends in the application of gamification in high school science subjects, and its impact on students' skills. While these dimensions provide valuable insights, future research could expand the scope to include other important perspectives, such as teachers' pedagogical strategies, game design characteristics, and assessment approaches. The pedagogical implications of this study suggest that physics teachers can integrate game activities with guided discussions to make the learning of physics concepts more meaningful. The gamification approach promotes the use of innovative instructional strategies that not only enhance learning outcomes but also foster intrinsic motivation and active engagement among students. In the context of physics education, such applications can help students better understand abstract concepts such as energy, motion, and force through exploratory learning experiences.

CONCLUSION

This study conducted a systematic literature review to examine the characteristics of games and their potential in science learning at the high school level from 2017 to 2024. The study found that technology and traditional games have been widely integrated into gamification. Research trends indicate a dominance of gamified products in chemistry, often used to enhance understanding of abstract concepts. The literature highlights that games are effective tools for learning and reviewing material comprehension. Additionally, variations in question types within games can increase student engagement and provide opportunities for future research, particularly in developing board games across diverse learning contexts. Various studies have reported that gamification in learning develops many skills, including learning outcomes, motivation, conceptual understanding, critical thinking, and mathematical representation.

Future research should focus on several areas that remain underexplored. These include examining the effects of gamification on skills such as collaboration, anxiety reduction, retention, cognitive abilities, academic performance, self-efficacy, and science literacy. Further investigations are needed to explore the potential for developing board games across diverse learning contexts, as well as to expand gamification research into physics and biology.

ACKNOWLEDGMENTS

None.

REFERENCES

Alahmari, M., Jdaitawi, M. T., Rasheed, A., Abduljawad, R., Hussein, E., Alzahrani, M., & Awad, N. (2023). Trends and gaps in empirical research on gamification in science education: A systematic review of the literature. *Contemporary Educational Technology*, *15*(3), 431. https://doi.org/10.30935/cedtech/13177

Al-Hafdi, F. S., & Alhalafawy, W. S. (2024). Ten Years of Gamification-Based Learning: A Bibliometric Analysis and Systematic Review. *International Journal of Interactive Mobile Technologies*, *18*(7), 188–212. https://doi.org/10.3991/ijim.v18i07.45335

Atoulloh, A., Fitriani, A., & Daryono, R. W. (2024). Exploring the Influence of Game-Based Learning and School Environment on Learning Achievement: Does the Mediation of Self-Intention Matter? *IJORER: International Journal of Recent Educational Research*, *5*(3), 623–638. https://doi.org/10.46245/ijorer.v5i3.597

Bibic, L., Druskis, J., Walpole, S., Angulo, J., & Stokes, L. (2019). Bug Off Pain: An Educational Virtual Reality Game on Spider Venoms and Chronic Pain for Public Engagement. *Journal of Chemical Education*, *96*(7), 1486–1490. https://doi.org/10.1021/acs.jchemed.8b00905

Cahyana, U., Paristiowati, M., Savitri, D. A., & Hasyrin, S. N. (2017). Developing and Application of Mobile Game Based Learning (M-GBL) for High School Students Performance in Chemistry. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(10). https://doi.org/10.12973/ejmste/78728

Christopoulos, A., & Mystakidis, S. (2023). Gamification in Education. *Encyclopedia*, *3*(4), 1223–1243. https://doi.org/10.3390/encyclopedia3040089

da Silva Júnior, J. N., de Lima Castro, G., Silveira Jucá, R. C., Nunes, F. M., Janô Nobre, D., Melo Leite Junior, A. J., Oliveira Alexandre, F. S., Silva de Sousa, U., & Monteiro, A. J. (2024). Vikings: An Online Cooperative Game for Reviewing Thermochemistry, Chemical Equilibrium, and Chemical Kinetics. *Journal of Chemical Education*, *101*(6), 2413–2421. https://doi.org/10.1021/acs.jchemed.3c01310

da Silva Júnior, J. N., Nobre, D. J., do Nascimento, R. S., Torres, G. S., Leite, A. J. M., Monteiro, A. J., Alexandre, F. S. O., Rodríguez, M. T., & Rojo, M. J. (2018). Interactive Computer Game That Engages Students in Reviewing Organic Compound Nomenclature. *Journal of Chemical Education*, *95*(5), 899–902. https://doi.org/10.1021/acs.jchemed.7b00793

Dziob, D. (2020). Board Game in Physics Classes—a Proposal for a New Method of Student Assessment. *Research in Science Education*, *50*(3), 845–862. https://doi.org/10.1007/s11165-018-9714-y

Fauziah, A. N., & Sulisworo, D. (2022). Pembelajaran Fisika dengan Memanfaatkan Teknologi Guna Meningkatkan Minat Belajar. *Jurnal Genesis Indonesia*, *1*(02), 79–86. https://doi.org/10.56741/jgi.v1i02.93

Fitriyana, N., Wiyarsi, A., Ikhsan, J., & Sugiyarto, K. H. (2020). Android-Based-Game and Blended Learning in Chemistry: Effect on Students' Self-Efficacy and Achievement. *Jurnal Cakrawala Pendidikan*, *39*(3), 507–521. https://doi.org/10.21831/cp.v39i3.28335

Giang, N. T., Van, D. N., Hong, N. P. N., Bao, C. Do, Phuong, T. N., & Phuong, T. T. T. (2025). Applying Augmented Reality Technology in STEM Education: A Bibliometrics Analysis in Scopus Database. *European Journal of Educational Research*, *14*(1), 73–87. https://doi.org/10.12973/eu-jer.14.1.73

Gupta, P., & Goyal, P. (2022). Is Game-Based Pedagogy Just a Fad? A Self-Determination Theory Approach to Gamification in Higher Education. *International Journal of Educational Management*, *36*(3), 341–356. https://doi.org/10.1108/IJEM-04-2021-0126

Haimovich, I., Yayon, M., Adler, V., Levy, H., Blonder, R., & Rap, S. (2022). "The Masked Scientist": Designing a Virtual Chemical Escape Room. *Journal of Chemical Education*, *99*(10), 3502–3509. https://doi.org/10.1021/acs.jchemed.2c00597

Hariyono, E., Rizki, I. A., Lestari, D. A., Citra, N. F., Islamiyah, A. N., & Agusty, A. I. (2023). Engklek Game Ethnoscience-Based Learning Material (EGEBLM) to Improve Students' Conceptual Understanding and Learning Motivation. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 635–647. https://doi.org/10.15294/jpii.v12i4.43941

Hou, H.T., Wu, C.S., & Wu, C.H. (2023). Evaluation of a Mobile-Based Scaffolding Board Game Developed by Scaffolding-Based Game Editor: Analysis of Learners' Performance, Anxiety and Behavior Patterns. *Journal of Computers in Education*, *10*(2), 273–291. https://doi.org/10.1007/s40692-022-00231-1

Jayanta, I. N. L., Suprianti, G. A. P., Ganing, N. N., & Utami, I. G. L. P. (2025). Digital Learning Innovation: Gamification-Based Smart System Adaptive Mobile Learning Needs Analysis Using the Tri Kaya Parisudha Approach for English Language Learning. *International Journal of Language Education*, *9*(2), 392–414. https://doi.org/https://doi.org/10.26858/ijole.v1i2.75116

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A.I. (2021). Gamification in Science Education: a Systematic Review of the Literature. *Education Sciences*, *11*(1), 1–36. https://doi.org/10.3390/educsci11010022

Karakose, T., Tülübaş, T., & Papadakis, S. (2022). Revealing the Intellectual Structure and Evolution of Digital Addiction Research: An Integrated Bibliometric and Science Mapping Approach.

International Journal of Environmental Research and Public Health, *19*(22), 14883. https://doi.org/10.3390/ijerph192214883

Katanosaka, T., Khan, M. F. F., & Sakamura, K. (2023). Design and Implementation of a Gamification-Based Web Application for Learning High-School Physics. *2023 14th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI)*, 200–205. https://doi.org/10.1109/IIAI-AAI59060.2023.00049

Kozub, H., Bakhov, I., Palamarchuk, S., Burak, V., & Lohvynenko, O. (2024). Adaptation of digital gamification in professional education amid martial law challenges. *Salud, Ciencia y Tecnología - Serie de Conferencias*, *3*. https://doi.org/10.56294/sctconf2024.1236

Lathwesen, C., & Eilks, I. (2024). Can You Make it Back to Earth? A Digital Educational Escape Room for Secondary Chemistry Education to Explore Selected Principles of Green Chemistry. *Journal of Chemical Education*, *101*(8), 3193–3201. https://doi.org/10.1021/acs.jchemed.4c00149

Leitão, R., Maguire, M., Turner, S., & Guimarães, L. (2022). A systematic evaluation of game elements effects on students' motivation. *Education and Information Technologies*, *27*(1), 1081–1103. https://doi.org/10.1007/s10639-021-10651-8

Li, C., Liang, L., Fryer, L. K., & Shum, A. (2024). The use of leaderboards in education: A systematic review of empirical evidence in higher education. *Journal of Computer Assisted Learning*, *40*(6), 3406–3442. https://doi.org/10.1111/jcal.13077

Lutfi, A., Aftinia, F., & Eka Permani, B. (2023). Gamification: Game as a medium for learning chemistry to motivate and increase retention of student learning outcomes. *Journal of Technology and Science Education*, *13*(1), 193. https://doi.org/10.3926/jotse.1842

Lutfi, A., Hidayah, R., Sukarmin, S., & Dwiningsih, K. (2021). Chemical bonding successful learning using the "Chebo collect game": A case study. *Journal of Technology and Science Education*, *11*(2), 474. https://doi.org/10.3926/jotse.1265

Lutfi, A., Hidayah, R., Hidayah, R., Aftinia, F., Aftinia, F., Ipmawati, N., & Ipmawati, N. (2023). House of Chemistry as a Hydrocarbon Learning Media for High School Students. *Educación Química*, *34*(1), 176–187. https://doi.org/10.22201/fq.18708404e.2023.1.82798

Martins, D., Fernandes, C., Campos, M. J., & Campos Ferreira, M. (2024). Gamification Approaches to Immigrants Experiences and Issues. *The International Journal of Information, Diversity, & Inclusion (IJIDI)*, 83–102. https://doi.org/10.33137/ijidi.v8i1.41453

Meng, C., Zhao, M., Pan, Z., Pan, Q., & Bonk, C. J. (2024). Investigating the impact of gamification components on online learners' engagement. *Smart Learning Environments*, *11*(1), 47. https://doi.org/10.1186/s40561-024-00336-3

Montagnani, S., Stefanel, A., Chiofalo, M. L. M., Santi, L., & Michelini, M. (2023). An experiential program on the foundations of quantum mechanics for final-year high-school students. *Physics Education*, *58*(3), 035003. https://doi.org/10.1088/1361-6552/acb5da

Nasiroh, A. Q. A., Lira, L., Sari, I. P., & Akhsan, H. (2025). Application Of Bessel Equation To Circular Slit Fraunhofer Diffraction: A Systematic Review. *EduFisika: Jurnal Pendidikan Fisika*, *10*(1), 54–64. https://doi.org/10.59052/edufisika.v10i1.42657

Noor, F. M., Rahayu, A., Handayani, N., Anwari, M. K., & Widyaningrum, S. (2022). Global Trend of Science Edutainment Research in The Last Ten Years. *Thabiea: Journal of Natural Science Teaching*, *5*(2), 204–215. https://doi.org/http://dx.doi.org/10.21043/thabiea.v5i2.19190

Oliveira, H., Figueiredo, G., Pereira, B., Magalhães, M., Rosário, P., & Magalhães, P. (2025). Understanding Children's Perceptions of Game Elements in an Online Gamified Intervention: Contributions by the Self-Determination Theory. *International Journal of Human–Computer Interaction*, *41*(16), 10163–10177. https://doi.org/10.1080/10447318.2024.2431363

Owens, A. D., & Hite, R. L. (2022). Enhancing student communication competencies in STEM using virtual global collaboration project-based learning. *Research in Science & Technological Education*, *40*(1), 76–102. https://doi.org/10.1080/02635143.2020.1778663

Pavey, S. (2021). *Playing Games in the School Library Developing Game-Based Lessons and Using Gamification Concepts*. Facet Publishing.

Preston, R., Gratani, M., Owens, K., Roche, P., Zimanyi, M., & Malau-Aduli, B. (2020). Exploring the Impact of Assessment on Medical Students' Learning. *Assessment & Evaluation in Higher Education*, *45*(1), 109–124. https://doi.org/10.1080/02602938.2019.1614145

Putranta, H., Kuswanto, H., Hajaroh, M., Astuti Dwiningrum, S. I., & Rukiyati. (2021). Strategies of Physics Learning Based on Traditional Games in Senior High Schools during the Covid-19 Pandemic. *Revista Mexicana de Física E*, *19*(1 Jan-Jun). https://doi.org/10.31349/RevMexFisE.19.010207

Rahayu, M. S., & Kuswanto, H. (2021). The Effectiveness of the Use of the Android-Based Carom Games Comic Integrated to Discovery Learning in Improving Critical Thinking and Mathematical Representation Abilities. *Journal of Technology and Science Education*, *11*(2), 270. https://doi.org/10.3926/jotse.1151

Richter, K., & Kickmeier-Rust, M. (2025). Gamification in Physics Education: Play Your Way to Better Learning. *International Journal of Serious Games*, *12*(1), 59–81. https://doi.org/10.17083/ijsg.v12i1.858

Riquelme, A., de Prado, J., Bonache, M. V., Rams, J., Sánchez, M., Torres, B., Rodriguez, M. D. E., Rodrigo, P., & Muñoz, B. K. (2024). Table Games as a Tool to Learn about Material Science in Engineering and Architecture Studies. *Education Sciences*, *14*(10), 1054. https://doi.org/10.3390/educsci14101054

Rizki, I. A., Suprapto, N., Saphira, H. V., Alfarizy, Y., Ramadani, R., Saputri, A. D., & Suryani, D. (2024). Cooperative model, digital game, and augmented reality-based learning to enhance students critical thinking skills and learning motivation. *Journal of Pedagogical Research*. https://doi.org/10.33902/JPR.202423825

Rossi, S., Rossi, C., & Accorigi, N. (2020). Quasiperiodic Crystals: Teaching Aperiodicity of a Crystal Lattice with 3D-Printed Penrose Tiles. *Journal of Chemical Education*, *97*(5), 1391–1395. https://doi.org/10.1021/acs.jchemed.9b00702

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Sari, F. P., Nikmah, S., Kuswanto, H., & Wardani, R. (2020). Development of physics comic based on local wisdom: Hopscotch (engklek) game android-assisted to improve mathematical representation ability and creative thinking of high school students. *Revista Mexicana de Física E*, *17*(2 Jul-Dec), 255–262. https://doi.org/10.31349/RevMexFisE.17.255

Sasikala, P., & Ravichandran, R. (2024). Study on the Impact of Artificial Intelligence on Student Learning Outcomes. *Journal of Digital Learning and Education*, *4*(2), 145–155. https://doi.org/10.52562/jdle.v4i2.1234

Saxena, M., & Mishra, D. K. (2021). Gamification and Gen Z in Higher Education. *International Journal of Information and Communication Technology Education*, *17*(4), 1–22. https://doi.org/10.4018/IJICTE.20211001.oa10

Sitorus, L. S., Sipahutar, M. I., Nasution, S. N., Purnama, L., & Iskandar, T. (2025). Literature Review on the Use of Technology-Based Learning Media in the Context of Distance Learning. *Jurnal Medika: Medika Universitas Pahlawan Tuanku Tambusai*, *4*(3), 283–289. https://doi.org/https://doi.org/10.31004/bkxg7355

Situmorang, R. P., Suwono, H., Munzil, M., Susanto, H., Chang, C.-Y., & Liu, S.-Y. (2024). Learn biology using digital game-based learning: A systematic literature review. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(6), em2459. https://doi.org/10.29333/ejmste/14658

Suryanarayana, K. S., Kandi, V. S. P., Pavani, G., Rao, A. S., Rout, S., & Siva Rama Krishna, T. (2024). Artificial Intelligence Enhanced Digital Learning for the Sustainability of Education Management System. *The Journal of High Technology Management Research*, *35*(2), 100495. https://doi.org/10.1016/j.hitech.2024.100495

Villamor, E. G., & Lapinid, M. R. C. (2022). The Use of Gamified Differentiated Homework in Teaching General Chemistry. *TEM Journal*, *11*(2), 594–604. https://doi.org/10.18421/TEM112-13

Yunus, E., & Zaibon, S. B. (2021). Connecting Computational Thinking (CT) Concept with the Game-Based Learning (GBL) Elements. *International Journal of Interactive Mobile Technologies*, *15*(20), 50–67. https://doi.org/10.3991/ijim.v15i20.23739