The Impact of Game-Based Learning on Cognitive and Affective Outcomes in Science Education: A Systematic Review

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Abstract – *This study aims to examine the implementation of Game-Based Learning (GBL) and its impact on students' cognitive and affective abilities in science learning during the 2020–2025 period. The method used was a Systematic Literature Review (SLR) by examining articles indexed in the Scopus and ScienceDirect databases. Based on established inclusion and exclusion criteria, 45 articles were selected and systematically analyzed. The study results indicate that GBL is implemented through various game formats, including digital games, live games, and games based on local culture. The predominant use of digital games aligns with current technological developments and student characteristics. The research findings indicate that GBL positively contributes to improving students' cognitive abilities, such as conceptual understanding, problem-solving skills, memory, and academic achievement. Furthermore, GBL also has a positive impact on affective aspects, including student motivation, engagement, and self-efficacy. These results indicate that GBL can create a more interactive, meaningful, and student-centered learning experience. This study confirms that GBL is an effective approach to supporting science learning while simultaneously developing students' cognitive and affective abilities. These findings provide implications for schools and educational policymakers to support GBL integration by providing adequate resources and strengthening teacher competencies. Future research is recommended to expand the scope of the literature and examine the effectiveness of various types of GBL in more diverse contexts and educational levels espesially in science or physics education.*

Keywords: *Game-Based Learning; Students' Cognitive; Students' Affective; Science Education.*

INTRODUCTION

Physics learning is still faced with classic problems, namely low student learning motivation and difficulty in understanding abstract concepts that require good understanding, one of the causes is a weak learning process (Ristiani, 2022). According to Djamaluddin & Wardana (2019), the learning process includes all interactions in the learning environment between teachers and students as well as learning resources in achieving the desired learning objectives, in line with the opinion of Lytras & Housawi (2023) hat a good learning process must be able to provide opportunities for students to play an active role in every learning carried out. In reality, learning is still considered passive and boring, making student motivation less, therefore an innovative approach is needed, especially those based on games and digital interactivity, which have great potential in overcoming these problems, one of which is the game-based learning approach.

Game-based learning (GBL) is defined as an approach that refers to learning with game design (either through learning media or playing activities) to achieve educational goals (Ding et al., 2024) so that this approach is one of the innovative and dynamic learning approaches.

Despite being an innovative learning tool, GBL still has limitations when implemented in schools, such as teacher readiness (Low et al., 2024), time allocation that needs to be adjusted, and the complexity of game design (Sun et al., 2024). This reflects the gap between the ideal situation where the implementation of game-based learning is systematically planned with pedagogical principles, but in practice, it tends to be disorganized, poorly evaluated, and has little or no impact on learning.

Various studies have shown that well-planned game-based learning positively contributes to improving science learning outcomes. Research conducted by Richter & Kickmeier-Rust (2025) found that gamified games can increase student engagement and performance, while also increasing motivation, although the results showed varying degrees of variation. Furthermore, research by Liu et al., (2023) found that developing game media can introduce and increase students' interest and passion for new, abstract concepts.

Recent years have witnessed a growing interest in game-based learning (GBL) as an innovative instructional approach capable of enhancing student engagement, motivation, and learning outcomes. The increasing integration of digital technologies into education has encouraged educators and researchers to utilize games as meaningful learning environments that support active participation, problem-solving, and knowledge construction. Previous studies have demonstrated that GBL can foster both cognitive and affective learning outcomes, making it a promising pedagogical strategy across various educational contexts (Küçük Yüceyurt & Altiner Yaş, 2025; Villatoro Moral et al., 2026).

Evidence supporting the effectiveness of GBL has been reported in several disciplines. For example, Villatoro Moral et al. revealed that video games have been successfully employed in history education to promote historical understanding, digital literacy, critical thinking, and inquiry-based learning through immersive and interactive experiences. Küçük Yüceyurt and Altiner Yaş also found that GBL has been widely implemented in nursing education, where digital games, simulations, and mobile-based applications significantly improved students' learning performance, motivation, critical thinking, and practical skills. Furthermore, a recent meta-analysis conducted by Soriano-Sánchez et al. demonstrated that GBL positively influences motivation, self-efficacy, and academic achievement in Natural Sciences learning (Soriano-Sánchez et al., 2026). These findings collectively suggest that GBL has considerable potential to improve learning across a wide range of educational disciplines.

Despite these promising findings, research specifically focusing on physics education remains relatively limited. Although the meta-analysis by Soriano-Sánchez et al. included several studies related to physics, most of the reviewed research concentrated on broad Natural Sciences domains such as biology, chemistry, and general science, with only a small proportion addressing physics-specific learning contexts. Moreover, existing studies have predominantly examined outcomes such as motivation, self-efficacy, and academic achievement, while relatively little attention has been given to the role of GBL in facilitating conceptual understanding of physics concepts. This limitation is particularly important because physics learning often involves abstract phenomena that are difficult to visualize and understand through conventional instruction. Therefore, further research is needed to investigate how game-based learning can be designed and implemented to support conceptual understanding, scientific reasoning, and problem-solving skills in physics education, thereby extending the existing body of knowledge on GBL beyond its currently established benefits for motivation and academic performance.

Therefore, this study reviews articles published over the last five years to provide a comprehensive overview of the development of Game-Based Learning (GBL) research, particularly in science and physics education. To achieve this objective, the study is guided by the following Research Questions (RQs): (a) How has Game-Based Learning (GBL) been implemented in general science and physics education across different educational levels (elementary school, junior high school, senior high school, and higher education)?; and (b) What are the effects of Game-Based Learning (GBL) on students' cognitive and affective learning outcomes in science and physics education?.

RESEARCH METHODS

This study uses a Systematic Literature Review (SLR) approach to examine how Game-Based Learning (GBL) is implemented at various levels of education (elementary, middle, high, and tertiary) and its impact on various student abilities and affective aspects in general science and physics learning. The SLR approach was chosen because it allows researchers to systematically identify all relevant studies on a particular topic, ensuring that the review is comprehensive and unbiased. (Kalibatiene & Miliauskaitė, 2026).

The framework used in this study refers to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). PRISMA is a commonly used method in preparing SLRs as it provides clear stages in the search, selection, and reporting of study results,thus enhancing the validity and transparency of the research outcomes (Page et al., 2021).

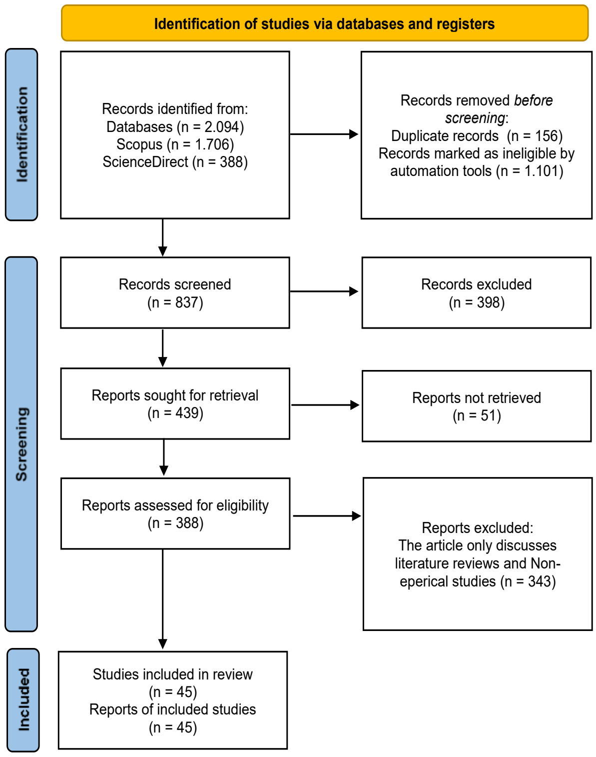

Figure 1. PRISMA Stages

Data were collected from several leading academic databases such as ScienceDirect and Scopus. The articles reviewed were scientific publications published between 2020 and 2025 to ensure that the analyzed literature reflects the latest developments in the application of the GBL approach at all levels of education in general science and physics learning and its impact on students' abilities and affective.

The initial database search identified 2,094 records, including 1,706 articles from Scopus and 388 articles from ScienceDirect. Following the removal of duplicate records and the application of automated screening procedures using Zotero and Rayyan, 837 articles remained for further evaluation. The inclusion and exclusion criteria were subsequently applied, resulting in 439 potentially relevant articles. Full-text accessibility was then assessed, leading to the exclusion of 51 articles that were unavailable for full-text review. Consequently, 388 articles proceeded to the eligibility assessment stage. During this stage, articles were evaluated to ensure that they constituted empirical research and did not represent review-based studies, such as Systematic Literature Reviews (SLRs). After the final eligibility screening, 45 articles met all selection criteria and were included in the review.

The search was conducted using keywords sucs as for Sciendirect using ("game-based learning" AND physics) and for Scopus using ("game-based learning" OR "educational game" OR "serious game" OR "digital game" OR "gamification" AND "physics" OR "science learning" OR "STEM education" OR "conceptual understanding" OR "science education").

Inclusion and Excluion Criteria

Inclusion creiteria include:

- The study investigated the implementation or impact of Game-Based Learning (GBL), serious games, educational games, or digital game-based learning in science or physics education.
- The study was conducted at various levels of education (elementary, middle, high school, and college or university students).
- The study employed empirical research methods, including experimental, quasi-experimental, mixed-methods, or research-and-development (R&D) designs with evaluation of learning outcomes.
- The journal article publication meets the criteria for a reputable journal in Scopus/ScienceDirect.

Exclusion criteria include:

- The article is a literature review, systematic review, meta-analysis and does not provide original empirical evidence.
- The article is not relevant to the context of science education.
- The article is not available in full text.

Screening and Analysis Procedures

The systematic stages were carried out through four phases in the PRISMA diagram:

- Identification: The researcher identified a number of articles based on the keywords.
- Screening: Irrelevant articles based on title and abstract were eliminated.
- Eligibility: The remaining articles were thoroughly read to assess content suitability.
- Inclusion: Articles that met all the criteria were further analyzed to extract themes.

The analysis was thematic, with articles grouped according to their focus areas, such as educational level, game type, and subject matter.

To ensure the methodological rigor of the included studies, a quality assessment was conducted using an adapted version of the Critical Appraisal Skills Programme (CASP) framework. Given the diversity of research designs in this review, including experimental, quasi-experimental, and development studies, the original CASP checklist was modified to better suit the context of educational research. The adapted quality appraisal framework consisted of six main sections encompassing seven assessment items: (A1) clarity of research aims, (B1) appropriateness of research design, (B2) adequacy of sample, (C1) validity and reliability of instruments, (D1) rigor and transparency of data analysis, (E1) clarity of findings, and (F1) discussion of limitations. Each item was rated on a three-point scale (0 = not reported, 1 = partially reported, 2 = clearly reported), resulting in a maximum possible score of 14 for each study. All included studies were independently evaluated based on these criteria. To enhance consistency, the assessment followed predefined scoring guidelines. Studies were then categorized into three quality levels based on their total scores: low quality (0–6), moderate quality (7–10), and high quality (11–14). The quality assessment results indicated that the majority of the included studies were classified as high quality (n = 39), while six studies were categorized as moderate quality (n = 6). No studies were classified as low quality. All studies achieved the maximum score for research aim clarity (A1) and clarity of findings (E1), indicating that research objectives and outcomes were consistently reported. Most studies also demonstrated appropriate research designs (B1) and transparent data analysis procedures (D1). However, several methodological weaknesses were identified in relation to sample adequacy (B2), instrument validity and reliability (C1), and the discussion of study limitations (F1). Among these criteria, the reporting of study limitations was the least frequently addressed, with only approximately one-third of the studies receiving the maximum score. These findings suggest that, although the overall methodological quality of the reviewed studies was satisfactory, greater attention should be given to reporting research limitations and instrument quality in future Game-Based Learning studies in science and physics education.

RESULTS AND DISCUSSION

Result

This Systematic Literature Review (SLR) examines the impact of implementing games in general science (science education) and physics learning at all levels of education on students' abilities and affective development. The following table summarizes 45 relevant articles.

Tabel 1. Systematic Literature Review of 45 Journals

No.	Article Title	Authors	Method	Result
1.	Adaptive Gamification in Science Education: Impact of Implementation on Students' Motivation	Zourmpakis et al.	Quantitative (quasi-experimental)	Adaptive gamification boosts motivation and positive perceptions because students feel more engaged and comfortable with games that adjust to their preferences.
2.	An Augmented Reality Serious Game for Children's Optical Science Education: Randomized Controlled Trial	Liu et al.	Quantitative (quasi-experimental)	The use of augmented reality (AR) games can effectively motivate students to improve conceptual understanding during science education.
3.	Assessing the Effectiveness of Board Game-based Learning for Enhancing Problem-Solving Competency of Lower Secondary Students.	Assapun & Thummaphan.	Mix-method with embeded design	The implementation of this board game improves problem-solving competency and science process skills and creates a positive learning experience
4.	Board Game in Physics Classes—a Proposal for a New Method of Student Assessment	Dziob	Quantitative	Using board games as assessment tools can enhance student achievement and motivation compared to not using

No.	Article Title	Authors	Method	Result
				games. They also improve students' attitudes toward learning and offer valuable collaborative learning experiences.
5.	Can Serious Games Reduce Electric Current Misconceptions among 10th Grade Moroccan Science Pupils?	Achour et al.	Quantitative (quasi-experimental)	Serious games significantly reduced students' misconceptions and improved their understanding of the concept of electric current.
6.	Cooperative model, digital game, and augmented reality-based learning to enhance students' critical thinking skills and learning motivation	Rizki et al.	RnD with Quantitative (quasi-experimental)	A Cooperative and Adventuring Physics (CAP)-based learning model with a game application can improve critical thinking skills and motivation by creating a dynamic and engaging learning environment for students.
7.	Collaborative Learning Based on Sophisticated Thinking Laboratory (STB-LAB) and Gather Town as	Agustina et al.	Quantitative (quasi-experimental)	STB-LAB, with the help of GatherTown as a gamification tool, can improve collaborative skills in both Physics and Biology
	Gamification Tool for Blended Laboratory on Science Undergraduate Students			Education students.
8.	DiGIBST: An inquiry-based digital game-based learning pedagogical model for science teaching	Caparoso & Orleans	RnD with Quantitative (experimental)	Digital game-based learning with the DiGIBST model can enhance junior high school students' achievement and motivation in science.
9.	Do You Want to Learn Physics? Please Play Angry Birds (But With Epistemic Goals)	Aldama & Pozo	Quantitative (quasi-experimental)	The results of this study indicate that playing Angry Birds, for example, can improve students' conceptual understanding and enable them to connect one concept to another related to parabolic motion.
10.	Educational Efficiency And Students' Involvement of Teaching Approach Based on Game-Based Student Response System	Radulovic	Quantitative (pedagogical experiment with parallel group)	The implementation of the Game-Based Student Response System (GSRS) significantly improved student performance and reduced mental effort compared to

No.	Article Title	Authors	Method	Result
				conventional approaches.
11.	Empowering the Next Generation: Using Minecraft Education to Teach Solar Photovoltaic Concepts in Secondary School	Sulaiman et al.	Mix-method	Minecraft enhances student retention, supports collaboration, and builds problem-solving and creativity, while guiding the development of game-based media in science education.
12.	Establishing a Model for Serious Science Game Design for Elementary Learners: A Longitudinal, Mixed Methods Study of Serious Game Design Mechanics That Facilitate Science Learning	Hodges & Flanagan	Mix-method	Games improve conceptual understanding; audiovisuals increase interest; encourage cooperative systems learning; game visuals support student engagement.
13.	Evaluating the Impacts of NTC Learning System on the Motivation of Students in Learning Physics Concepts Using Card-Based Learning	Lazarevic et al.	Quantitative (pedagogical quasi experiment)	Using NTC4memory cards increased student motivation by making learning more engaging, while also improving cognitive skills like thinking speed, attention,
	Approaches			creativity, teamwork, and helping identify gifted students
14.	Evaluation of Interactive Game-Based Learning in Physics Domain	Zeng et al.	Quantitative (quasi-experimental)	The game's interaction, feedback, and simulations improved engagement, retention, and understanding of force, energy, and motion, showing that GBL effectively links theory and practice.
15.	Force and motion misconceptions in Moroccan high school science majors: insights from video game activity	Bouzid et al.	Quantitative (quasi-experimental)	The study found that students who played video games showed different misconception patterns on the FCI, indicating an impact on their understanding of physics concepts.
16.	From In-Game Behaviors to Learning Gains: Constructing Bayesian Networks for Stealth Assessment	Lu et al.	Quantitative (Learning Analytics/Data Mining (Non-experimental))	The study shows that game-based assessments can predict skill improvements, such as argumentation, and help maintain students' learning motivation.
17.	Game-Based	Holly et al.	Quantitative	VR games can boost

No.	Article Title	Authors	Method	Result
	Motivation: Enhancing Learning with Achievements in a Customizable Virtual Reality Environment		(experimental A/B test)	student motivation and engagement when achievements are added, but too many elements can increase cognitive load.
18.	Gamification in Physics Education: Play Your Way to Better Learning	Richter & Rust	Quantitative (crossover design)	The study shows that gamified learning boosts student engagement, performance, and motivation, although the effects variation.
19.	Gamified experimental data on physics experiment to measuring the acceleration due to gravity	Saprudin et al.	Quantitative (quasi-experimental)	Gamification in physics experiments boosts student engagement by making the activities more enjoyable, competitive, and motivating.
20.	Gamifying Physics Laboratory Work Increases Motivation and Enhances Acquisition of the Skills Required for Application of the Scientific Method	Okariz et al.	Quantitative	The findings of this study indicate that laboratory sessions with gamification elements can increase students' extrinsic motivation and, consequently, inspire their intrinsic motivation and improve their learning performance.
21.	Gamifying Teacher Education with FantasyClass: Effects on Attitudes towards Physics and Chemistry among Preservice Primary Teachers	Valverde et al.	Mix-method	The results show that the gamification approach increases student engagement and motivation and effectively prepares prospective educators to implement innovative and engaging teaching strategies.
22.	Impact of Digital Game-based Learning Experiences on Reasoning Skills and Science Engagement	Debchaudhury	Quantitive (Randomized-controlled trial)	Games increase engagement in scientific activities, students' self-efficacy, and their understanding of proper scientific work practices.
23.	Improving Students' Cognitive Abilities and Motivation in Kinematics Material Through Egamerasi Media	Saputro et al.	Quantitative (quasi-experimental)	The EGAMERASI game on movement can improve cognitive abilities from C1 to C6 and increase student motivation.
24.	Improving the Conceptual Understanding of	Pulot et al.	Quantitative (one-group pretest-posttest design)	The implementation of a game integrated with local

No.	Article Title	Authors	Method	Result
	Grade 9 Learners Using Biotrail-Larong Pinoy: A Photosynthesis Quest			culture, Larong Pinoy, effectively improved Grade 9 students' conceptual understanding of science material.
25.	Influence of a Two-Tier Test and Self-Efficacy on Students' Problem-Solving Tendencies, Knowledge Gains, Cognitive Load, and Behaviors in a Game-Based Learning Context	Tsao et al.	Quantitative (quasi-experimental)	The results show that two-tier test learning and high self-efficacy boost problem-solving tendencies and cognitive load, but do not significantly improve knowledge gain.
26.	Innovative Learning Activities for Ethnically Diverse Students in Macedonian Science Education	Rusevska et al.	Quantitative	Pre-test scores showed no difference, but post-test results revealed significant gaps between middle and elementary students in science interest, self-concept, and motivation.
27.	Inquiry-Enhanced Digital Game-Based Learning: Effects on Secondary Students' Conceptual Understanding in Science, Game Performance, and Behavioral Patterns	Chen et al.	Quantitative (quasi-experimental)	The findings showed that the group with POE learning and games performed significantly better in conceptual understanding and game performance.
28.	Integrating immersive virtual reality technology in scaffolded game-based learning to enhance low motivation students' multimodal science learning	Ding et al.	Mix-method with embeded design	The results showed that the group using the VR Game was effective in improving science knowledge, even though students had lower motivation than the group using the desktop version of the game.
29.	Integrating Ivatan Indigenous Games to Learning Module in Physics: Its Effect to Student Understanding, Motivation, Attitude, and Scientific Sublime.	Moro & Billote	RnD (ADDIE) with Quantitative (quasi-experimental)	Traditional game-based modules significantly improve conceptual understanding, motivation, and positive attitudes toward physics.
30.	Learning Newtonian mechanics with an intrinsically integrated educational game	Linden et al	Mix-method	The study showed that students improved their conceptual understanding, could transfer knowledge to the game, and showed no difference in

No.	Article Title	Authors	Method	Result
				intrinsic integration whether they used correct or incorrect concepts.
31.	Leveraging augmented reality and gamification for enhanced self-regulation in science education	Ates & Polat	Quantitative (experimental)	Students using the AR game with self-regulation showed higher achievement, engagement, self-efficacy, and satisfaction than those using the AR game alone.
32.	Mastering the Game: How Level Structure and Game Elements Shape Competency Acquisition	Ritcher et al.	Quantitative (crossover design)	The group with the gamified learning version had significantly higher levels of engagement and learning performance without causing excessive cognitive load compared to the group without gamified learning.
33.	Optimization of Physics Learning Through Immersive Virtual Reality: A Study on the Efficacy of Serious Games	Castillo et al.	Quantitative (experimental)	The integration of this VR-based game into learning resulted in significant improvements in students' conceptual understanding and encouraged higher engagement and motivation, thus complementing traditional or conventional methods.
34.	Path of knowledge: promoting the learning of the first law of thermodynamics and its applications through a serious game	Nascimento et al.	Design Science methodological approach	The Path of Knowledge increased students' intrinsic and extrinsic motivation, creating a more dynamic, interactive, and enjoyable learning environment with greater autonomy and high engagement.
35.	PhyGame: An Interactive and Gamified Learning Support System for Secondary Physics Education	Katanosaka et al.	RnD And Mix-method	This study found that incorporating gamification concepts into an online physics learning system can increase student engagement and motivation in learning physics.
36.	PhyLab – a virtual reality laboratory for experiments in physics: a pilot study on	Korlat et al (2024)	Quantitative (quasi-experimental)	Physics scores were similar between groups except on the third test, but the experimental class

No.	Article Title	Authors	Method	Result
	intervention effectiveness and gender differences			showed higher interest, self-efficacy, involvement, and motivation, with mostly male participants.
37.	Physics XP: Integration of ChatGPT and Gamification to Improve Academic Performance and Motivation in Physics 1 Course	Clemente & Vega	Quantitative (experimental)	The study shows that integrating AI-based games improves achievement, motivation, participation, and receives positive student feedback.
38.	Qupcakery: A Puzzle Game that Introduces Quantum Gates to Young Learners	Liu et al.	IRB-approved study with Mix-method	Qupcakery successfully increased student interest in quantum concepts, though its difficulty level is more suitable for high school than junior high students.
39.	Serious game-based learning and learning by making games: Types of game-based pedagogies and student gaming hours impact students' science learning outcomes	Ding & Yu	Quantitative (quasi-experimental)	The findings of this study indicate that different game-based learning approaches and students' weekly gaming hours result in different science learning outcomes.
40.	Serious Games Model for Higher-Order Thinking Skills in Science Education	Noh et al	RnD (ADDIE) and Mix-method	Serious games significantly increase HOTS and motivation by creating new learning that is more interesting, interactive, and effective than traditional methods.
41.	The Effect of Supporting Science Education with Gamified E-Learning Environments on Motivation and Achievement	Bayrak & Sonmez	Mix-method	The results showed that supporting students with a gamified e-learning environment improved their academic achievement and motivation compared to the curriculum-recommended method.
42.	The Effect Of The Use Of Indigenous Knowledge-Based Physics Comics of Android-Based Marbles Games on Verbal Representation And Critical Thinking Abilities In Physics Teaching	Damayanti & Kuswanto	Quantitative (quasi-experimental)	The use of local knowledge-based physics comics: an Android-assisted marble game in learning is more effective in improving critical thinking and verbal representation skills compared to learning using PowerPoint.

No.	Article Title	Authors	Method	Result
43.	The Effects of Adaptive Gamification in Science Learning: A Comparison Between Traditional Inquiry-Based Learning and Gender Differences	Zourmpakis et al.	Quantitative (quasi-experimental)	The findings showed both groups improved, but the experimental group scored higher, with gender differences also improving significantly in that group.
44.	The Power of Play: Investigating the Effects of Gamification on Motivation and Engagement in Physics Classroom	Gaurina et al.	Quantitative (experimental)	Gamification improves the learning experience by increasing motivation and engagement, while encouraging students to collaborate in solving challenging problems.
45.	The Relationship between Collaborative Problem-Solving Skills and Group-to-Individual Learning Transfer in a Game-based Learning Environment	Sun et al.	Quantitative (experimental)	The results showed that only one of the three CPS (maintaining a positive team dynamic) skills predicted student learning outcomes.

This Systematic Literature Review (SLR) aims to examine the impact of game-based learning in science and physics education across all educational levels on students' cognitive abilities and affective outcomes. The analysis of 45 selected articles provides a comprehensive overview of how various types of educational games have been designed, implemented, and utilized in science, particularly physics, education over the past five years. The findings reveal the following:

- Most of the research involved samples from high school students.
- Several articles also used Research and Development (R&D) methods to develop game media for implementation in learning.
- The research used a mixed-methods approach to explore the impact of game implementation on improving students' abilities and affective skills.
- Based on the selected journal articles, the game media implemented in learning mostly used digital games such as games with augmented reality (AR), virtual reality (VR), and video games.

In general, effective game-based learning (GBL) includes:

- Thorough and focused learning planning (including the selection of appropriate models, strategies, and learning materials).
- Availability of game media designs, both digital and non-digital.
- Adapted to the characteristics and needs of students.
- A supportive curriculum.
- Innovation in learning models (e.g., cooperative learning models).

Table 2. Article Grouping Based on Educational Level

No.	Educational Level	Total Articles	Article Numbers (base on main Table 1)
1.	Elementary School (SD)	7	1, 2, 12, 25, 39, 40, 43,
2.	Junior High School (SMP)	10	3, 8, 11, 22, 23, 24, 27, 28, 31, 41
3.	Senior High School (SMA)	13	4, 5, 6, 9, 10, 14, 15, 18,

No.	Educational Level	Total Articles	Article Numbers (base on main Table 1)
			29, 32, 35, 42, 44
4.	Undergraduate Student (PT)	9	7, 17, 19, 20, 21, 33, 34, 37, 45
5.	Mixed/non-specific	6	13, 16, 26, 30, 36, 38

As shown in Table 2, the majority of GBL studies were conducted at the senior high school level (28.9%), followed by junior high school (22.2%) and higher education (20%). The higher concentration of research at the senior high school level may reflect the complexity of science and physics content taught at this stage, thereby necessitating the use of innovative learning approaches to promote students' conceptual understanding and motivation to learn.

Table 3. Article Grouping Based on Types of Games

No.	Game Type	Total Articles	Article Numbers (base on main Table 1)
1.	Game Apps	4	6, 9, 11, 25
2.	Board and Card Games	4	3, 4, 13, 34
3.	Game Digital (VR/AR)	28	1, 2, 5, 7, 8, 12, 14, 15, 16, 17, 18, 21, 22, 25, 26, 27, 28, 30, 31, 32, 33, 35, 36, 38, 39, 41, 43, 45
4.	Quizzes	2	10, 37
5.	Live Game Activities	4	19, 20, 40, 44
6.	Local Games	3	24, 29, 42

Table 3 shows the grouping of selected articles (2020–2025) based on game type, where many implement digital game media such as virtual and augmented reality (e.g., Agustina et al., 2024; Jiménez-Valverde et al., 2024).

As shown in Table 3, digital games were the most frequently implemented type of Game-Based Learning (GBL), appearing in 28 of the 45 reviewed studies (62.2%). This finding reflects the growing influence of educational technology on the adoption of virtual reality (VR), augmented reality (AR), and other digital game-based applications in science education. Conversely, local games, quizzes, and board games were less frequently utilized, although these approaches may offer valuable opportunities to promote student engagement and integrate culturally relevant learning experience.

Based on the analysis of the 45 studies that satisfied the inclusion criteria, the publication distribution of Game-Based Learning (GBL) research in science and physics education between 2020 and 2025 showed a fluctuating pattern across the years. The trend of GBL-related publications over the review period is presented in Figure 1.

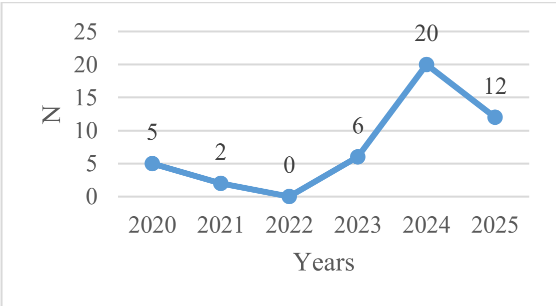

Figure 2. Publication Trends

As shown in Figure 2, a total of 5 studies (11.11%) were published in 2020, followed by 2 studies (4.44%) in 2021, while no studies meeting the inclusion criteria were identified in 2022 (0%). Subsequently, the number of publications increased to 6 studies (13.33%) in 2023, reached a peak of 20 studies (44.44%) in 2024, and slightly declined to 12 studies (26.67%) in 2025. Overall, these findings indicate a growing research interest in the implementation of Game-Based Learning (GBL) in science and physics education. This trend may be attributed to advancements in digital technology, the increasing adoption of interactive learning media, and the demand for more engaging and student-centered instructional approaches. The lower number of studies identified between 2020 and 2022 may be associated with the limited availability of research that specifically focused on GBL implementation in science and physics education and met the predefined inclusion criteria of this review.

Furthermore, the analysis revealed several recurring challenges in implementing Game-Based Learning (GBL) in science and physics education. The most commonly reported challenge involved the emergence of misconceptions or inaccurate conceptual understanding, particularly when game mechanics and learning objectives were not sufficiently aligned. In addition, several studies highlighted increased cognitive load caused by excessive or overly complex game elements. Challenges related to the suitability of game difficulty levels for learners at different educational stages were also identified. Moreover, variations in learning outcomes were reported across student groups, including differences by educational level and gender. Collectively, these findings indicate that while GBL is generally associated with positive cognitive and affective outcomes, its effectiveness may depend on multiple instructional and learner-related factors that require careful consideration during implementation.

Discussion

The findings of the systematic literature review show that the application of game-based learning in learning, especially general science and physics, plays an important role in improving the quality of science learning, in line with constructivism learning theory and learning motivation theory (Urhahne & Wijnia, 2023).

The effectiveness of GBL may be explained through constructivist learning theory (Fosnot & Perry, 2019), which emphasizes active knowledge construction through interaction and exploration. By engaging students in problem-solving activities and immediate feedback systems, GBL creates meaningful learning experiences that enhance conceptual understanding and learning motivation. These findings support the theoretical perspective of Plass et al. (2015), who identified challenge, response, and feedback as the three core components of effective Game-Based Learning (GBL). Within this framework, challenges are presented through tasks and problem-solving activities integrated into the game, responses are demonstrated through learners' interactions and decision-making processes, and feedback is delivered through scores, points, achievements, or other forms of performance evaluation. The interaction among these components fosters active participation, sustained engagement, and increased motivation, thereby enhancing the overall learning experience.

In addition, the effectiveness of Game-Based Learning (GBL) is influenced by several factors, including engaging game design, alignment with students' characteristics, consistency with curriculum objectives, and integration with appropriate instructional models. Several studies have shown that combining GBL with supportive pedagogical approaches, such as competition-based cooperative learning, can further enhance student engagement, motivation, and learning outcomes.

In addition, findings related to the impact on the abilities and affective (e.g. motivation) of students are:

First, conceptual understanding ability, game media can influence conceptual understanding for students, one of the studies conducted by Bouzid et al., (2025) stated that students who actively play games can influence or change their understanding of actual physics concepts (allowing misconceptions to occur) or it could be the other way around, like research conducted by Achour et al., (2025) that games can reduce misconceptions and thus improve conceptual understanding.

Second, problem solving skills, games through the GBL approach can help train these skills, as research by Assapun & Thummaphan (2023) stated that GBL can stimulate students to improve problem-solving competencies for real-world problems.

Third, GBL can improve critical thinking skills (Rizki et al., 2024) and higher order thinking skill (HOTS) (Noh et al., 2024).

Fourth, GBL can improve students' achievements (learning outcomes), as research conducted by Dziob (2020) and Saputro et al., (2025) shows that GBL can create active learning experiences, thereby improving students' achievements.

Fifth, the retention ability of students in research by Sulaiman et al., (2024) and Zeng et al., (2020) stated that retention ability (memory strength) increased after games were implemented in learning.

Sixthly, in the affective domain, it was found that students' motivation, involvement, and self-efficacy were more dominant, as in research by Zourmpakis et al., (2023) and Nascimento et al., (2025), the results showed that after implementing GBL, students' motivation, involvement, and self-efficacy increased, but these three things could also decrease if GBL learning added or included too many game elements that could increase students' cognitive load (Holly et al., 2024).

Various types of games from the selected research are indeed effective in training students' abilities and increasing students' affective abilities such as motivation and involvement, but the author highlights the existence of research that combines GBL with local culture, namely in research by Pulot et al., (2025), Moro & Billote (2023) and Damayanti & Kuswanto (2021) stated that in addition to effectively improving students' abilities and affective (motivation and involvement), it also introduces and re-popularizes local cultural values in today's digital era.

Despite the generally positive outcomes reported across the reviewed studies, Game-Based Learning (GBL) may not consistently produce favorable learning effects. Some studies highlighted the potential for excessive cognitive load when learners are exposed to highly complex game environments (Holly et al., 2024), while others reported that poorly designed game-based activities may reinforce existing misconceptions rather than promote conceptual understanding (Bouzid et al., 2025) and additionally, learning outcomes may be negatively affected when game difficulty exceeds learners' cognitive and developmental readiness (Liu et al., 2023). Beyond these instructional challenges, the effectiveness of GBL is also shaped by contextual factors such as educational level, technological accessibility, cultural background, and classroom environment. The widespread use of digital games, virtual reality (VR), and augmented reality (AR) in recent studies further suggests that technological infrastructure plays a critical role in determining the feasibility and effectiveness of GBL implementation across different educational settings.

Moreover, variations in learner characteristics and educational settings may partly explain the differences in outcomes reported across studies. As noted by Low et al. (2024), the effectiveness of GBL depends not only on the quality of the game design but also on teachers' preparedness to integrate game-based activities into meaningful learning experiences. Consequently, future research should investigate GBL implementation across diverse educational environments, cultural contexts, and learner groups. Longitudinal studies are particularly recommended to provide deeper insights into the sustained impact of GBL on students' cognitive achievement and affective development over time.

CONCLUSION

Based on the systematic review of studies published between 2020 and 2025, it can be concluded that Game-Based Learning (GBL) is an effective instructional approach for enhancing students' learning outcomes in science education, particularly in both cognitive and affective domains. GBL has been implemented through various forms of games, including digital games, live-action games, and local culture-based games, with digital games emerging as the most frequently utilized type, reflecting current technological advancements and the characteristics of contemporary learners. The findings indicate that GBL contributes to improvements in conceptual understanding, problem-solving skills, knowledge retention, and academic achievement. Furthermore, GBL has been shown to enhance students' learning motivation, engagement, and self-efficacy, thereby fostering more meaningful and effective learning experiences.

From a theoretical perspective, these findings reinforce existing literature suggesting that GBL serves not only as a strategy for improving academic performance but also as an instructional approach capable of simultaneously promoting students' affective development. Therefore, this review provides a more comprehensive understanding of the role of GBL in supporting student-centered science learning and facilitating the holistic development of learners' competencies.

Nevertheless, this study has several limitations. First, the review was restricted to articles retrieved from selected databases and published within a specific time frame, which may have resulted in the exclusion of other relevant studies. Second, the review focused primarily on identifying implementation patterns and reported outcomes rather than quantitatively measuring effect sizes across studies. Therefore, future research is recommended to expand the scope of literature sources, compare the effectiveness of different forms of GBL including digital and non-digital games and investigate the long-term effects of GBL on learning outcomes and twenty-first-century skills across various educational levels.

From a policy perspective, the findings highlight the importance of support from schools and educational policymakers in integrating GBL into science instruction. Such support may include providing adequate technological infrastructure and learning resources, developing game-based instructional materials, and offering professional development opportunities for teachers to enhance their capacity to design and implement game-based learning activities effectively in alignment with curriculum objectives and learning outcomes.

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