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Educational Game Media as a 21st Century Science Learning Innovation: A Bibliometric Review

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ABSTRACT

Objective: The development of digital technology has encouraged the use of game-based learning media as an innovation to improve the effectiveness of physics learning, which is often considered difficult by students. This study aims to comprehensively examine the effectiveness of game-based learning media in physics learning. **Methods:** Research used is a Systematic Literature Review (SLR) that analyzes various studies on the implementation of game-based learning in physics education. **Results:** The study involved researching and analyzing 20 scientific articles related to the application of games as learning media for science. The results showed that the use of game-based media can improve students' understanding of scientific concepts, motivate them to learn, and increase their participation in the learning process. Effectively designed games can create a fun and challenging learning experience, allowing students to apply science concepts in a relevant context. In addition, factors such as providing appropriate feedback, adjusting the level of difficulty, and incorporating social interaction in the game also play a role in enhancing the effectiveness of game-based learning media. Further research is needed to deepen understanding of how to optimize the use of game media in physics learning. **Novelty:** The novelty of this study lies in a comprehensive synthesis of the effectiveness of game-based learning media in physics learning, while identifying its potential for development as an innovative learning strategy that integrates digital technology and 21st-century competency needs.

INTRODUCTION

The quality of a nation's education reflects the progress of the nation itself (Komalasari & Yakubu, 2023; Muhajir, 2022). Quality education will give rise to the next generation that is innovative, creative, and able to contribute to societal progress (Nasir et al., 2023; Sepulveda-Escobar & Morrison, 2020). With the advancement of the digital era, information and communication technology has permeated various fields, including education (Sibagariang et al., 2023; Thunyaniti & Wuttirom, 2019). One of the significant developments in the world of education is game learning media, which has emerged as an interesting and innovative tool in improving the effectiveness of learning (Manolev et al., 2019; Safitri et al., 2022). This is very helpful for the learning process because it can increase students' interest in certain subjects and help them improve conceptual understanding (Mao et al., 2022; Pramita & Putri, 2023).

Educational games are a form of game used to provide learning to students through simple, understandable game media (Jammaludin et al., 2023; Suliyanah et al., 2021). Literature on the effectiveness of game-based learning media in physics has been a concern for researchers and educators in recent years (Low et al., 2023). Previous studies have shown that the use of game-based learning media can increase students' interest

and motivation, facilitate a better understanding of physics concepts, and develop cognitive and problem-solving skills (Cardinot et al., 2022; Susilawati et al., 2022). Spann (2019) explained that abstract concepts can be experienced and learning improved through a game-based learning process. Using game-based learning strategies associated with digital technology to integrate 21st-century skills (Dakhi et al., 2020).

Game-based learning involves designing learning to be more interesting and meaningful, so that, in the end, learning is more effective and innovative (Troussas et al., 2020; Tuan et al., 2024). Physics, as one of the subjects often considered difficult by students (Jufirda et al., 2019), requires a creative and interactive learning approach to improve understanding of complex concepts (Rahim et al., 2022). Game-based learning media offers great potential to facilitate a more interesting, interactive, and effective physics learning process (Mudjid et al., 2022; Suri et al., 2022). Research on the benefits of game-based learning media in physics education still lacks a comprehensive understanding of their effectiveness. Therefore, this study aims to conduct a comprehensive literature review on the effectiveness of game learning media in physics subjects (Lutifah et al., 2024).

The novelty of this research lies in presenting a comprehensive literature synthesis on the effectiveness of game-based learning media in physics learning (Gomez et al., 2022; Safitri et al., 2025). Unlike previous research that generally focuses on the implementation of games in specific materials or educational levels, this study integrates various empirical findings to identify patterns of effectiveness, pedagogical benefits, and the contribution of game-based learning to increasing learning motivation, understanding of physics concepts, problem-solving skills, and the development of 21st-century skills (Robberts & Ryneveld, 2022). Furthermore, this study also maps the potential for integrating digital technology into game-based learning media as an innovative learning strategy to address educational challenges in the digital era (Ratnasari et al., 2023).

RESEARCH METHOD

This research uses a content analysis method and collects data through a literature review. After collecting several journals related to games and learning outcomes, the data were analyzed using qualitative descriptive analysis through a literature review (Flemban, 2024). This research uses a qualitative approach that produces descriptive data in the form of written and oral sentences from people and observations of behavior from experiments conducted. Activities in qualitative data analysis include four stages, namely:

1. Data collection is the process of collecting data in the field (both from journal reviews and experiments) to obtain the information needed so that the research objectives can be achieved.
2. Data reduction is summarizing, selecting key things, and focusing on important things so that the data obtained has a clear picture, and makes it easier for researchers to take further data.

3. Data Display (presentation of data), the presentation of data in qualitative research, which is most often used, is narrative text in the form of brief descriptions, charts, relationships between subjects.

Conclusion and verification are about new findings that have never existed before. The research flow can be seen in Figure 1 below.



Figure 1. Research design in SLR

This research instrument consisted of a documentation sheet for identifying and recording key information from relevant articles (Khan & Mita, 2023; Rahaman et al., 2023). Data collection was conducted through a literature review, which identified 15 articles discussing the use of game-based learning media and its impact on learning outcomes. The extracted data included the article title, year of publication, type of game media used in learning, and its impact on learning outcomes (Guan et al., 2024; Wang et al., 2022). Furthermore, the data were analyzed using content and qualitative descriptive analyses, following the stages of data collection, data reduction, data presentation, and the drawing and verification of conclusions, to obtain a comprehensive picture of the effectiveness of game media in improving learning outcomes (Monaro et al., 2022; Nicmanis, 2024). The researcher collected 15 relevant articles. The keywords and information of the articles are 1) article title, 2) year of publication, 3) learning using game media, and 4) improving learning outcomes.

RESULTS AND DISCUSSION

Results

The literature review on Game-Based Learning found that game-based learning media have a positive influence on the student learning process (Bado, 2022; Putri et al., 2025). The effectiveness of good learning outcomes, student motivation, student creativity skill levels, and increased concept understanding. Visualization of game-based learning media and improving learning can be seen in Figure 2 below.

From the total literature, 15 articles were taken for review. The literature review that discusses the effectiveness of game learning media can be seen in Table 1.

Title	Author	Findings
Evaluation of Interavtive Game Based Learning in Physics	Hui Zeng, Shao-Na Zhou, Gui-Rong Hong, Giu-ye Li, Shao-Qiu Xu	The study was conducted among three different groups: the traditional group, the educational video group, and the game-based learning group. The results showed that the game-based learning group had the best performance among the three groups.
The Productive Role of Cognitive Reappraisal in Regulating Affect During Game	Catherine A. Spann, Valerie J. Shute, Seyedahmad Rahimi, Sidney K. D'Mello	Effective in exploring how game use can affect students' emotions and how Cognitive Reappraisal can play a role in regulating emotions.
Designing Physics board games: a practical guide for educators	Adriana Cardinot, Veronica McCauley, Jessamyn A Fairfield	Board games can be a highly engaging and motivating resource to support the teaching of physics at all levels of education.
Development of Smart Physics Card as Physics Learning Media on Temperature and Heat Material	Sri Latifah, K Koderi, Ida Fiteriani, Khoiruddin, Rahma Diani	Smart physics cards on temperature and heat materials meet the requirements that are very worthy of quality and very attractive to be used as learning media for class XI students.
Game Based Learning to Engage Students with Physics and Astronomy Using a Board Game	Adriana Cardinot, Jessamyn A. Fairfield	Results showed that this astronomy board game significantly improved students' knowledge of astronomy concepts and

Title	Author	Findings
		perceptions of scientists.
Effect of Concept Mapping Based Two Tier Test Strategy on Students' Digital Game Base Learning Performances and Behavioral Patterns	Feng-Ying Li, Gwo-Jen Hwang, Pei-Ying Chen, Yu-Jung Lin	It was concluded that the CM-TTG approach successfully had no significant impact on cognitive load, learning motivation, or student flow of experience.
Collaboration and Fuzzy Modeled Personalization for Mobile Game Based Learning in Higher Education	Christos Troussas, Akrivi Krouska, Cleo Sgoropoulou	It can help students in higher education to advance the level of knowledge.
The Effectiveness of Game Based Learning on The Logic Gate Topics	D Dewantara, M Wati, M Misbah, S Mahtari, S Haryandi	The effectiveness of the application of game-based learning is in the high category. Thus game-based learning on logic gate material is effectively applied to improve student learning outcomes.
Development of the Innovative Smart Orbital (ISO) Medium to Improve the Cognitive Skills on the Heat Transfer Concept	Firmanul Catur Wibowo, Esmar Budi, Lari Andreas Sanjaya	Using ISO media experience improvement of cognitive abilities on the concept of heat transfer.
A Modification of UNO Games: Chemuno Card Games (CCG) Based on Chemistry Triangle to Enhance Memorization of the Periodic Table	Ira Mahartika, Neti Afrianis, Heppy Okmarisa, Niki Dian Permana Putra	Effective in improving students' recall skills in chemistry subjects.
Penerapan Model Problem Based Learning (PBL) Berbantuan Media Kartu Bergambar Terhadap Kemampuan Berpikir Kritis dan Hasil Belajar Siswa dalam Pembelajaran Fisika SMK Negeri di Kabupaten Jember	Ika Permata Sari, Yushardi, Subiki	The use of learning media in the form of picture card games with PBL models is effective in improving student learning outcomes.
Simulasi Phet Sebagai Media Pembelajaran Berbasis Komputer Pada Model Pembelajaran Team Games Tournament Untuk Meningkatkan Aktivitas Dan Hasil Belajar Fisika Mahasiswa	Oktavianus Ama Ki'I, Egidius Dewa	The research shows that there is an increase in the physics learning outcomes of students with an average initial test and final test of 53 and 84 respectively. The increase is shown through the normality gain of 0.66 indicating that student learning outcomes increase with moderate criteria.

	Title	Author	Findings
11	The Effect of Quantum Learning Model Using Roulette Game on Physics Learning Outcomes	Tutumai Lestari, Yulia Rahmadhar, Feli Cianda Adrin Burhendi	Quantum learning with roulette game media has an influence on physics learning outcomes. Judging from the results of the posttest calculation at each meeting, the acquisition of learning outcomes has increased from 79.2 to 80.2 then the last posttest increased to 80.5. Quantum learning by using roulette games can improve physics learning.
7 39	Effects of Game-Based Learning on Students' Achievement in Science: A Meta-Analysis	Hao Lei, Ming Ming Chiu, Danyi Wang, Chenxin Wang, Tongwei Xie	The findings suggest that GBL has a significant positive influence on learner achievement in science learning. Factors such as engaging design, level of interactivity, and integration with learning materials emerged as important elements to achieving positive outcomes
6	Embedding game-based problem-solving phase into problem-posing system for mathematics learning	Kuo-En Chang, Lin-Jung Wu, Sheng-En Weng, Yao-Ting Sung	The result of the research is that the game-based problem-solving process in the problem formulation system significantly increases learner engagement, understanding of mathematical concepts, and learner ability to formulate problems
	Board Game in Physics Classes a Proposal for a New Method of Student Assessment	Daniel Dziob	The research findings show that the use of board games as an assessment method resulted in high engagement from learners, increased learning motivation, and significantly improved learners' concept understanding
1 28	Game-Based Learning Has Good Chemistry with Chemistry Education: A Three Level Meta-Analysis	Yuanyuan Hu, Timothy Gallagher, Pieter Wouters, Marieke van der Schaaf, Liesbeth Kester	This study aims to evaluate the effectiveness of game-based learning in chemistry education by comparing cognitive, motivational, and emotional outcomes between game-based and non-game-based. Game-based learning has a significant positive effect on cognitive with $g = 0.70$, indicating that the use of games has a better understanding of chemical concepts compared to other methods.
8	Effects of Game-Based Learning on Students' Critical Thinking: A Meta-Analysis	Weijie Mau, Yunhuo Cui, Ming M. Chiu, Hao Lei	This effect of GBL is in accordance with problem-based learning theory and the view that complex problems in GBL with imperfect information allow students to try different strategies to solve them, then provide feedback to help them evaluate their use of information and decisions, which

Title	Author	Findings
		improves critical thinking ability.
Media Pembelajaran Berbentuk Kartu dengan Metode Permainan UNO pada Materi Protista	Rahmi Aulya, Zulyusri, Rahmawati	The use of UNO card games in learning has a significant increase in students' understanding of protist material.
Development Of the Uno Chemical Card Game As A Learning Media On The Chemical Bonding Material For High School Student	Lilis Dahlianis, Iswendi	The results showed that UNO Chemical Card Game was successfully developed as an effective learning media, recognized by experts, and received positive responses from students. material validation of 0.92 and media validation of 0.92 are included in the valid category. Media practicality is obtained from the teacher's response of 96.8% and students who are included in the 94.4% practical category.

Discussion

Based on the keyword network visualization in Figure 2, game-based learning is the dominant theme. It serves as the center of the research network, as indicated by its largest node size and the number of connections to other keywords. This analysis identified several key interconnected clusters. The blue cluster focuses on aspects of learners and the learning process, such as students, motivation, academic performance, and instructional media. The green cluster relates to the implementation of game-based learning in educational contexts, encompassing e-learning, teaching, digital literacy, and serious games. The purple cluster highlights the relationship between game-based learning, gamification, and education. In contrast, the red cluster discusses the application of digital technology in learning, such as artificial intelligence, social media, and digital media. Furthermore, the yellow cluster highlights relatively new themes, such as the metaverse, game theory, and learning processes, which indicate the direction of future research. Overall, this bibliometric map shows that game-based learning research is developing multidisciplinary and has strong links to learning motivation, digital literacy, gamification, and educational technology innovation.

One of the effectiveness of GBL is also seen in research (Dewantara et al., 2020), which shows that the application of GBL on logic gate material is in the high category, indicating that this approach can improve students' understanding of complex material (Velaora et al., 2022). In addition, GBL also proved effective in improving students' cognitive abilities. Research by Latifah et al. (2020) found that physics smart cards on the concept of temperature and heat transfer can help students understand abstract concepts more easily. This is reinforced by research by Wibowo et al. (2020), who found that using Innovative Smart Orbital (ISO) media can improve students' cognitive abilities when learning the concept of heat transfer. Interactive media like this have been shown to

provide clear visualizations that facilitate students' understanding (Firat et al., 2022; Halliday et al., 2024). Critical thinking ability is also an important skill that can be improved through GBL. Mao et al. (2022), in their meta-analysis, found that problem-based games can improve students' critical thinking skills. In the field of science, especially chemistry, several meta-analyses show that GBL provides very positive results. Lei et al. (2022) found that GBL improved student achievement in science learning, with interactive elements and the integration of learning materials as key factors in success (Getened et al., 2024; Zou et al., 2025). Research by Hu et al. (2022) found that GBL positively affects understanding of chemistry concepts, with a significant increase in cognitive understanding compared to non-game methods.

CONCLUSION

Fundamental Findings: The results of this study indicate that the use of game-based learning media positively impacts student learning outcomes, motivation, engagement, and conceptual understanding. These findings indicate that integrating games into learning can be an effective strategy for creating more interactive, engaging, and meaningful learning experiences. **Implication:** This study underscores the need for educators to utilize game media as an alternative learning innovation to support the development of student competencies in the digital era. **Limitation:** However, this study has limitations because it analyzed only a limited number of relevant articles and did not examine the effectiveness of game media by educational level, subject matter, or specific game type. **Future Research:** Therefore, further research is recommended to conduct a broader study that draws on more literature and explores the influence of various types of game-based learning on students' cognitive, affective, and 21st-century skills.

AUTHOR CONTRIBUTIONS

Ecylovira Rizki Aini was manuscript writing, processed and analysed bibliometric data. **I Made Astra** performed data validation and discussion, supported the literature search, reference compilation, and final editing. All authors approved the final manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest, either financial or personal, that could influence the content or results of this study.

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This article has met the standards of research and publication ethics. The author affirms that this research is original, conducted with academic integrity, and free from unethical practices, including plagiarism.

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