Online Learning in Educational Research
Volume 5, Issue 1, 113-128.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index
DOI: 10.58524/oler.v5i1.626

Game-based Learning in Science Education: Bibliometric Analysis

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Article Info

Article history:

Received: February 25, 2025
Revised: May 29, 2025
Accepted: June 03, 2025

Keywords:

Bbibliometric Analysis;
Game-Based Learning;
Science Learning.

Abstract

Game-based Learning (GBL) in science education can increase students' interest, motivation, and involvement in the process of learning, so a more in-depth study of GBL through bibliometric analysis is needed. This study aims to analyze research trends on the application GBL in science education through bibliometric analysis from 2021-2024. This study employed bibliometric analysis to examine 349 English-language journal articles published from 2021 to 2024, which were retrieved from the Scopus database. Using VOSviewer, the analysis involved co-occurrence and keyword mapping to identify emerging research themes and publication trends. The results obtained 62 articles for further analysis through bibliometric review and visualization using VOSviewer. The trend of GBL research grows yearly, potentially increasing the number of publications the following year. The majority of GBL-related articles appear in respected international journals. This is also the reason for the article's high citation count. Indonesia ranks second in terms of GBL research. The visualization findings between GBL and science education demonstrate that various keywords under investigation emerged in the previous year. This further indicates a topic worth investigating further. The analysis results are based on the study topic, research location, type of research, and applications utilized in GBL, providing an overview for future researchers to undertake a more in-depth examination of the data. The main findings show that GBL may enhance the learning results of students in the context of science, providing insights into effective learning strategies that educators can adopt. These findings are expected to be used to formulate more innovative and effective educational practices and serve as a basis for further research in this area.

To cite this article: Haryandi, S., Misbah, M., Arlinda, R., Muhammad, N., Harto, M., & Qamariah, Q. (2025). Game-based learning in science education: Bibliometric analysis. *Online Learning in Educational Research, 5*(1), 113-128. https://doi.org/10.58524/oler.v5i1.626

INTRODUCTION

The increasing use of Game-Based Learning (GBL) in science education reflects a broader shift toward combining theoretical knowledge with creative teaching methods. Current studies emphasize that GBL can significantly improve student motivation and learning outcomes by presenting scientific content more engagingly and enjoyably (Al Faqih et al., 2023; Firdianika et al., 2023; Qondias et al., 2023; Perdana et al., 2023). GBL utilizes game elements to enhance students' learning experiences and make learning more engaging (Aulia et al., 2024). At its core, Game-Based Learning (GBL) involves thoughtfully incorporating game elements into instructional materials to create an engaging environment that meaningfully boosts students' motivation and curiosity (Badajos et al., 2023; Hosseini et al., 2019; Saba, 2024), fostering critical thinking, analytical, and problem-solving skills (Adipat et al., 2021; Indriyani et al., 2024; Kucher, 2021; Lameras et al.,

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2021). Scholarly sources indicate that GBL fosters a more participatory learning environment, enabling students to delve deeper into scientific principles and become more engaged (Freeman et al., 2014; Hermawan & Suharto, 2025).

Game-Based Learning (GBL) is an instructional method that uses elements such as objectives, rules, challenges, and feedback to produce an engaging and interactive learning experience (Islam et al., 2024). GBL plays an important role in science education, facilitating conceptual understanding of subjects such as physics, chemistry, biology, and earth science through active exploration and hands-on experience. The goal of science education is not only to transfer knowledge but also to shape scientific mindsets and higher-order thinking skills (Trimawati et al., 2020). As a quantitative research tool, bibliometric analysis reveals trends in scholarly output. It maps collaborations among researchers or institutions and highlights prominent keywords, providing insight into the progression of GBL practices in the science education (Zubaidah & Ninglasari, 2021). This method enables researchers to uncover meaningful insights. These insights can be about the progression of GBL. They can be found in both scholarly discourse and classroom application.

Although research on game-based learning (GBL) continues to expand, consistent application of GBL, particularly in science classrooms, still faces notable obstacles. While new frameworks for designing effective GBL are emerging, they are rarely adopted uniformly in real-world educational settings and are seldom grounded in a well-rounded pedagogical approach (Huizenga et al., 2017; Mohd et al., 2018). In addition, the lack of consensus among teachers regarding GBL's viability as an educational tool hinders its broader implementation (Huizenga et al., 2017; Yuan et al., 2022). Research on GBL has been widely discussed on the topics of Health (Hendrick et al., 2025; Nelson & Hewis, 2025), programming (Dzulkifly et al., 2025), business (Wang et al., 2019), mathematics (Juhanaini et al., 2025), and English (K. Sari et al., 2024). The use of GBL in scientific disciplines, such as physics, chemistry, and biology, remains relatively unexplored. This underscores the need for more research to enable the effective and widespread integration of GBL into science education.

Within this framework, bibliometric analysis is a valuable method for gaining comprehensive insights into the implementation and perception of Game-Based Learning (GBL) in science education. By examining publication trends, best practices, and unexplored areas, this analysis provides educators with the information necessary to develop evidence-based pedagogical strategies. Furthermore, it helps identify central research themes and prevalent academic discussions, guiding more targeted and impactful GBL applications. The outcomes of this analysis also provide valuable input for curriculum developers and policymakers to create learning designs that leverage games as meaningful tools for engaging students in scientific inquiry. With this in mind, the present study will explore research trends on the use of GBL in science education via a bibliometric analysis covering the years 2021 to 2024.

Specifically, this study wants to find out: 1) How many publications on GBL in science education were published from 2021 to 2024? ; 2) Which authors and countries contributed to the publications?; 3) What is the trend of keyword visualization in GBL publications in science education?; and 4) What are the material focuses, research locations, and research designs used in the GBL science education publications during this period?.

METHOD

This research is an example of bibliometric analysis. The five phases of bibliometric analysis are as follows: 1) research design; 2) data collection; 3) data analysis; 4) data visualization; and 5) interpretation (Hudha et al., 2020; Putra et al., 2024; Saregar et al., 2022; Zupic & Čater, 2015). The bibliometric research scheme on GBL is shown in Figure 1.

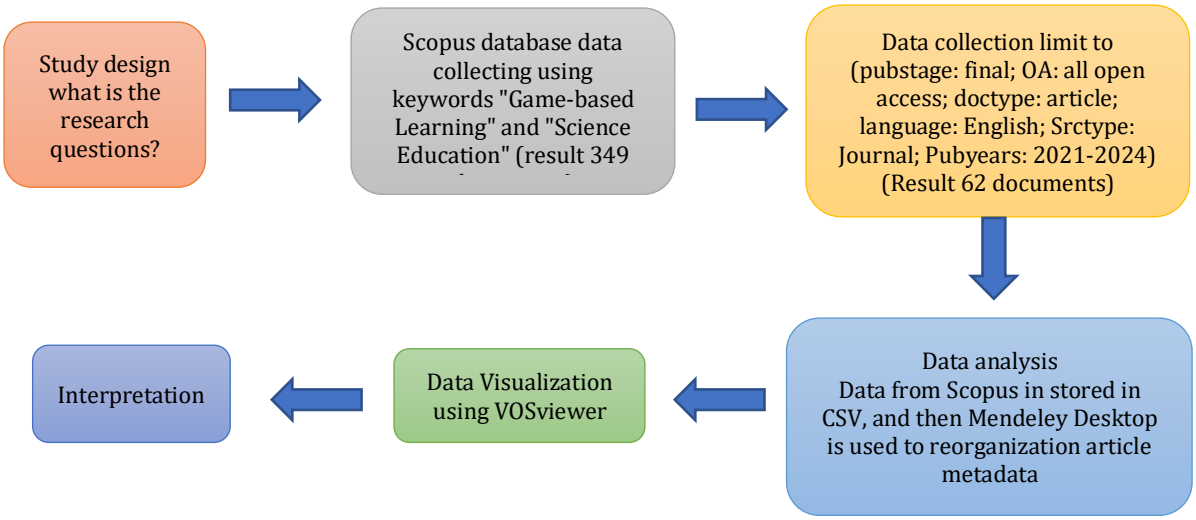

Figure 1. Bibliometric Research Plan on the Subject of Science Education via Game-Based Learning

Figure 1 shows that the initial step in this process begins with designing a research design and formulating a clear research question. This bibliometric study focuses on the implementation of Game-Based Learning (GBL) in the context of science education. The aim is to understand publication trends, contributing countries and authors, frequently used keywords, and thematic focus of GBL research in science education from 2021 to 2024. This step is important so that the entire analysis process runs according to the direction and objectives set. The second step, data collection, was carried out in December 2024 using the Scopus database. The keywords used in the search were "Game-Based Learning" and "Science Education," which resulted in 349 documents. These documents include various relevant international scientific publications. The results of this initial search serve as the basis for further data filtering so that the analysis focuses on quality sources relevant to the research topic.

The third step is to filter the dataset using strict inclusion criteria to ensure data relevance and quality. Filtering is done based on: publishing stage (final), year of publication (2021–2024), language (English), source type (journal), content type (article), and access type (open access). A total of 62 articles met all the inclusion criteria and were selected as the primary dataset for the bibliometric analysis. These publications represent the most relevant scholarly contributions to the discourse on Game-Based Learning (GBL) in science education in recent years. After selecting them, the corresponding metadata, including article titles, author names, institutional affiliations, publication years, keywords, and citation counts, was downloaded from the Scopus database in CSV format. Then, the metadata was managed and refined using the Mendeley Desktop application to ensure it was clean and well-organized for the next phase. This data preparation step is essential for maintaining consistency and accuracy before moving into the visualization and analysis stages.

The fifth step is to analyze the prepared metadata using version 1.6.18 of the VOSviewer software. VOSviewer is a powerful tool for building and visualizing networks, such as those representing collaboration between authors, keyword coexistence, and citation relationships between journals (Hamidah et al., 2020; Misbah et al., 2022; Pratiwi et al., 2022). This study employed VOSviewer to generate visual maps illustrating collaborative networks between countries, keyword frequency and co-occurrence, and connections among authors and academic journals. These visualizations reveal underlying patterns and emerging trends that traditional analytical methods may overlook. The final phase involves interpreting the visual outputs produced by VOSviewer. Maps of author collaboration and keyword clustering provide valuable insights into prevalent research themes, active areas of inquiry, and the structure of scholarly collaboration within the field. Citation analysis identifies the most impactful journals and influential authors contributing to GBL in science education. This interpretive process addresses the core research questions and enriches our understanding of the trajectory of the field, offering meaningful guidance to educators, scholars, and decision-makers in shaping future research and instructional strategies.

RESULTS AND DISCUSSION

The studies that the researchers used as data in this bibliometric analysis were published between 2021 and 2024. Figure 3 presents the distribution details of the primary studies from 2021 to 2024.

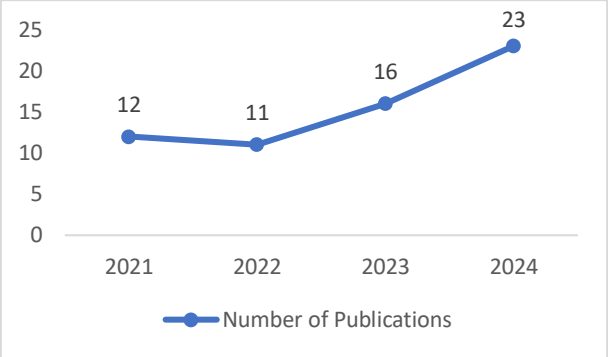

Figure 3. Article Publication Year on the Topic of GBL in Science Education

Figure 3 shows the trend of the number of publications on Game-Based Learning (GBL) in science education from 2021 to 2024. In 2021, there were 12 publications, which then decreased slightly to 11 in 2022. However, the trend increased significantly in the following two years, namely to 16 publications in 2023 and reaching a peak of 23 publications in 2024. This sharp increase indicates that researchers' attention and interest in applying GBL in science education are increasing, especially after 2022. This may reflect the increasing awareness of the importance of innovative learning approaches in improving the effectiveness of science teaching at various levels of education. This is due to the impact of the fourth industrial revolution and rapid technological advances (Febrianti et al., 2021; D. W. Sari et al., 2025). These technological advances have affected the education sector, including the integrated learning media (Handiyani & Abidin, 2023; Saputra et al., 2023). Table 1 provides details of the 10 most cited articles on this subject.

Table 1. Top 10 Most Cited Articles

No	Author (s)	Citations	Publisher	Findings	SJR/ Quartile
1	(Chen et al., 2021)	33	Springer Berlin	GBL is now used in science and math classes to lower learning anxiety and boost student motivation and engagement. The findings also show that, recently, research has focused more on higher-order thinking abilities, including critical thinking, problem-solving, and teamwork.	1.7/ Q1
2	(Falah et al., 2021)	30	Multidisciplinary Digital Publishing Institute (MDPI)	The benefits of virtual reality (VR) technology as a teaching and learning tool, as well as end users' readiness to employ VR systems as educational tools.	0.54/ Q2
3	(Avargil et al., 2021)	27	American Chemical Society	The "Escape Room-Based Educational Assessment" (EREA) was developed to serve secondary school chemistry teachers and their students as an alternative learning and assessment environment. A variety of puzzles	0.54/ Q2

No	Author (s)	Citations	Publisher	Findings	SJR/ Quartile
				are described in this activity paper. The escape room is equipped with a camera that records the student's work as they solve the puzzles, while at the same time, their teacher can observe them from a control room. The teacher is asked to provide feedback on the activity and to determine which puzzles require significant application of chemical knowledge, higher-order thinking skills (analysis, synthesis, or evaluation), and creative thinking for their solution.	
4	(Zourmpakis et al., 2023)	23	Multidisciplinary Digital Publishing Institute (MDPI)	An adaptive gamification environment increases students' motivation to learn science. Additionally, the majority of students found the game aspects incorporated into their courses enjoyable, demonstrating the efficacy of the multifaceted framework in improving student experience and engagement.	0.62/ Q2
5	(Pondee et al., 2021)	22	Springer Berlin	The Mobile Game-based Inquiry Learning in Science (MGILS) intervention results suggest the potential advantage of enhanced case-based TPACK support as opposed to the customary independent TPACK support. Potential enhancements to improve TPACK in mobile games were suggested after shortcomings in the use of MGILS modules were noted.	0.92/ Q1
6	(Shute & Rahimi, 2021)	22	Springer US	This studies the design and development of a range of Integrated learning resources into the Physics Playground game. The purpose of this 2D computer game is to teach pupils Newtonian physics, and it measures their comprehension of the subject directly through concealed evaluations. A few of our concepts exhibit encouraging outcomes. Using modelling (worked examples, physics videos), modalities (animations, formulas, definitions, Hewitt videos), and	1.84/ Q1

No	Author (s)	Citations	Publisher	Findings	SJR/ Quartile
				recommendations (hints), we describe the design, creation, and testing of a final suite of supports.	
7	(Lee et al., 2021)	18	Wiley-Blackwell Publishing Ltd	Comparing models of student participation in two types of interactive games: single-team and multi-team participatory simulation games (MPSG) participatory simulation games (SPSG). We found that in MPSG, social engagement predicted behavioral engagement, while in SPSG, students' emotional engagement played an important role. Students participating in MPSG performed better in systems thinking than those in SPSG.	2.43/ Q1
8	(Czok et al., 2023)	16	Multidisciplinary Digital Publishing Institute (MDPI)	The use of augmented reality (AR) in scientific instruction in both higher education and schools is growing. Learning motivation, comprehension of the learning process, and engagement may all be improved by combining virtual and actual information. This study uses the game-based AR learning environment "Beat the Beast" to examine the beneficial learning impacts of AR. Despite imposing a comparatively high cognitive burden, AR has no detrimental consequences on learning outcomes. In contrast to those in the alternative environment, learners in the AR context did not exhibit decreased information acquisition despite the higher cognitive load. Additionally, our research demonstrates how AR may improve user engagement and motivation.	0.67/ Q2
9	(Lameras et al., 2021)	16	Springer	From emphasizing rules and logic as a way to finish game levels to comprehending the intricacy of fundamental processes for fostering and transferring enquiry in games to actual classrooms, game design components significantly influence the idea of enquiry in games. This implies that various game design properties can be considered to	1.57/ Q1

No	Author (s)	Citations	Publisher	Findings	SJR/ Quartile
				extend the intrinsic inquiry experience in games to actual classroom inquiry practices.	
10	(Nkadimeng & Ankiewicz, 2022)	16	Springer Netherlands	Students are motivated, engaged, and challenged to think critically while collaborating, and the abstraction of atomic structures is reduced. While not all of the Minecraft Edu crafting station features to support active, in-depth learning of abstract concepts, it is clear that this crafting station has some capacity to make atomic structures less abstract for students.	1.6/ Q1

Based on Table 1, it is explained that in the study, GBL is increasingly adopted in science teaching to increase student motivation and engagement. GBL and interactive learning are the most frequently used keywords, which shows a strong trend in exploring these two educational themes (Chen et al., 2021). Current technologies, such as VR, show great educational potential (Falah et al., 2021). Students show increased motivation to learn science in a gamified environment (Zourmpakis et al., 2023). Participatory simulations in learning also encourage social interaction and better student engagement (Lee et al., 2021). The use of Minecraft Edu shows the potential to reduce the abstraction of difficult-to-understand concepts, such as atomic structure (Nkadimeng & Ankiewicz, 2022). This highlights the importance of curriculum design incorporating game aspects to create a more engaging learning environment. This study opens up opportunities for game-based interventions at various levels of education, showing its relevance in a broad learning context. Table 1 shows that authors with the highest citations are mostly published in Scopus-indexed journals in Quartile 1. This indicates that articles published in Q1 journals are more likely to be cited by other authors.

The high citation rate of studies integrating immersive technologies like VR and escape room scenarios may indicate a growing demand for experiential and engaging science instruction. These approaches possibly resonate with current educational shifts that emphasize student-centered and inquiry-driven learning environments. Figure 4 shows the results of the analysis based on the Co-Authorization of "Country" (Network Visualization).

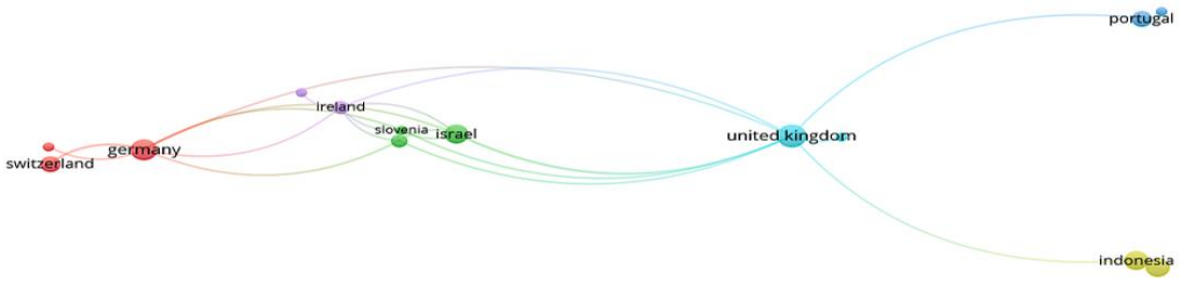

Figure 4. Co-Authorship *"Countries"* (Network Visualization) on the Topic of GBL in Science Education

Figure 4 shows a visualization of countries researching GBL in Science Education. The results show that the UK has six articles, with findings from these six studies focusing on multidisciplinary education, such as medicinal chemistry, which addresses challenges in traditional teaching methods that can hinder students' learning progress. Research shows that technologies such as VR and educational games can enhance learning by providing greater interactivity and engagement.

Techniques like MGCards and MMB work well for enhancing comprehension of abstract chemical ideas by taking a more interesting approach (Erlina et al., 2024; Falah et al., 2021; Kieferle et al., 2024; Lameras et al., 2021; Saraiva et al., 2024; Yachin & Barak, 2023). Indonesia has four articles, with findings from these four studies indicating that technology and mobile applications in education are increasing and can potentially improve students' higher-order thinking and communication skills. In addition, digital games positively impact increasing students' learning motivation, especially in science subjects. The limited understanding of students towards abstract concepts, especially in chemistry, is overcome by the development of interactive learning tools such as MGCards, which have effectively improved students' understanding of the concepts. The use of online gaming in biology education also shows a growing trend, which supports the development of 21st-century skills and constructivist learning approaches. All of these results highlight how crucial it is to use innovative teaching strategies and integrate technology to give students a successful and interesting learning environment (Afikah et al., 2022; Erlina et al., 2024; Safitri et al., 2022; Situmorang et al., 2024). The results of the Co-Occurrence analysis (Network Visualization) on the GBL topic are shown in Figure 5.

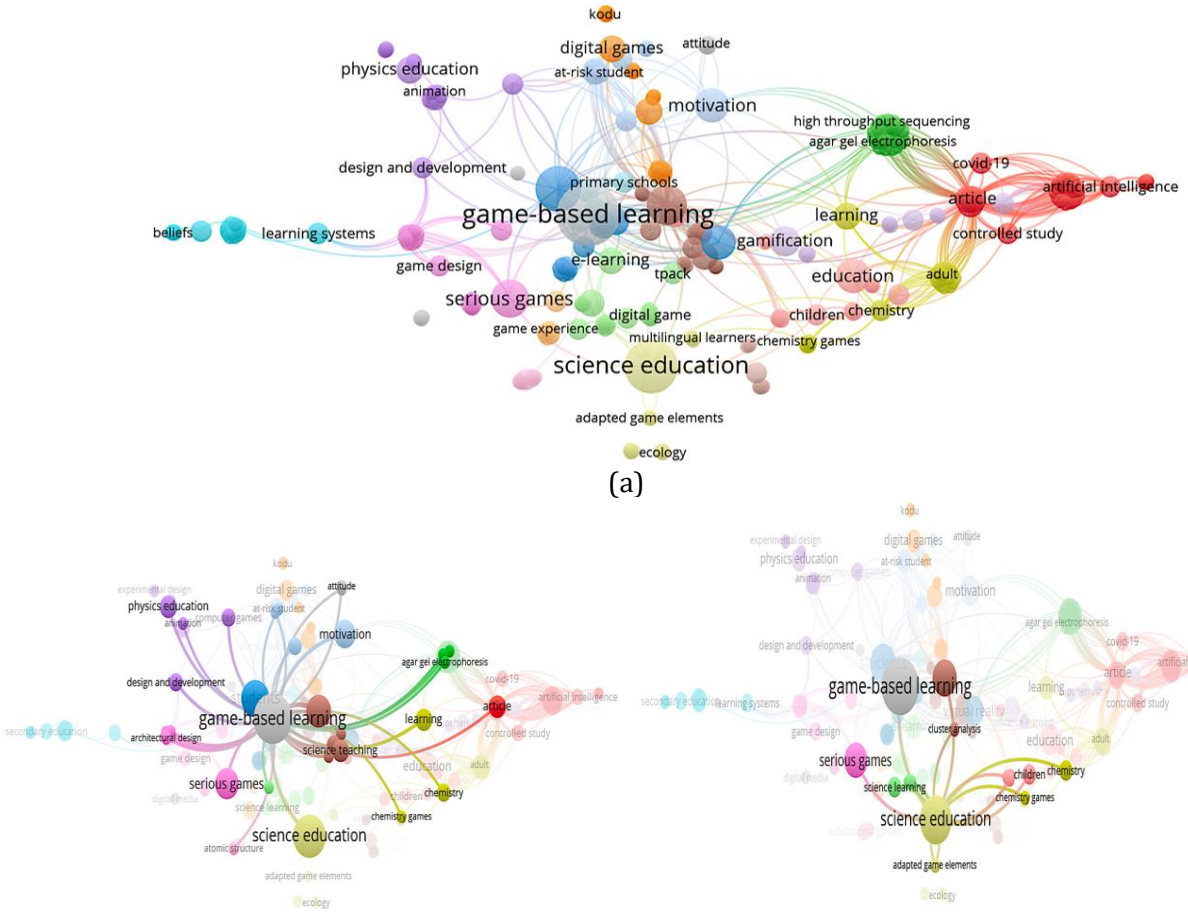

Figure 5. Co-Occurrence (Network Visualization) (a) on the Topic of GBL in General, (b) GBL Keywords, and (c) Science Education Keywords

Figure 5 shows that GBL is connected to chemistry, chemistry games, physics education, science teaching, science education, attitude, learning, animation, and serious games. The connection between GBL and science education is also large, seen from the distance that is not too far and the size of the circle between GBL and science education. In addition, Figure 5 shows that the keyword science education is connected to GBL, serious games, science learning, children, chemistry, chemistry education, etc. With a focus on "Game-Based Learning," which is connected to many terms such as "motivation," "serious games," and "science education," it is clear that GBL does not only focus on the game aspect but also includes motivational and didactic elements in the educational context. This is in line with research by Hamari et al. (2014) emphasized that

"motivation in Game-Based Learning is essential to enhance student engagement and learning outcomes. The focus on "motivation" and "serious play" highlights the potential of educational games to enhance student engagement in science learning. Gamification can enhance engagement and achievement in educational environments (Hamari et al., 2014). Emphasizing the importance of game elements in creating engaging and effective learning experiences. The results of Co-Occurrence (Overlay Visualization) on the GBL topic are shown in Figure 6.

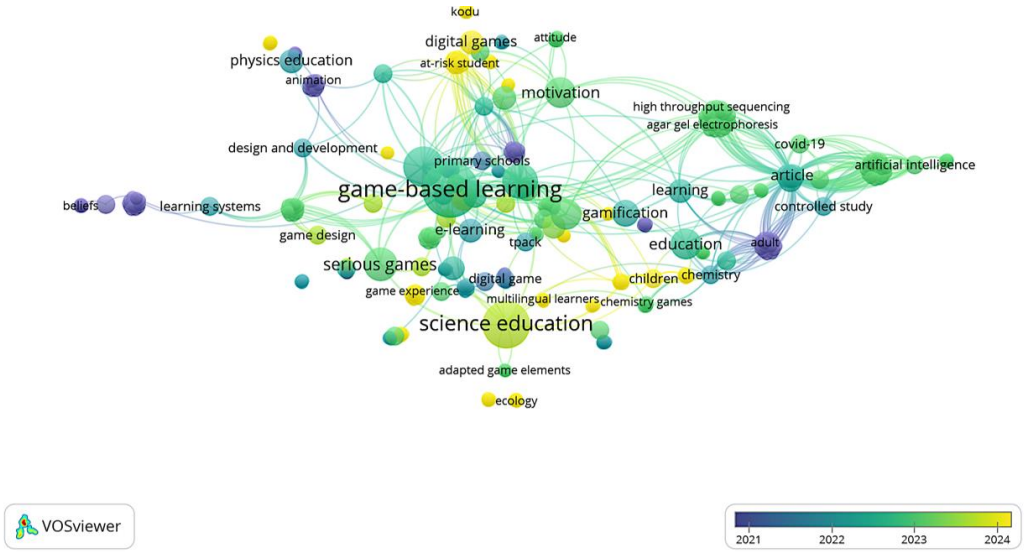

Figure 6. Co-Occurrence (Overlay Visualization) on the Topic of GBL in Science Education

Figure 6 shows that in the last 1 year, GBL has been related to game experience, digital games, children, ecology, at-risk students, multilingual learners, etc. Some of these keywords can be used as opportunities by researchers to conduct in-depth studies related to this. The application of the GBL research topics in focus material is presented in Table 2.

Table 2. Application of GBL in Focus Material

No	Focus Material	Frequency
1	Unknown	25
2	Physics	5
3	Chemistry	3
4	Electron Molecule	2
5	Ecosystem	2
6	Solar System	2
7	Life Science	2
8	Natural Science	2
9	Electrochemical Energy	1
10	Microbiology	1
11	Solar Photovoltaic (PV)	1
12	Monosaccharides	1
13	Periodic Table Elements	1
14	Quantum Mechanics	1
15	Biology	1
16	Science Literacy	1
17	Ecology	1
18	Optics	1
19	Laboratory	1
20	Microplastics	1
21	Genetics Concept	1
22	Projectile Kinematics	1
23	Newton	1

No	Focus Material	Frequency
24	Atomic Structure	1
25	Science Ethics	1
26	Electromagnetism	1
27	Microorganisms	1

Table 2 shows the application of GBL in various focus materials, with varying frequencies across different fields of study. Materials with the highest frequencies include physics (5), followed by specific chemistry and ecosystems topics, with frequencies of 3 and 2, respectively. This indicates that more complex and systematic materials like physics and chemistry may be more suitable for Game-Based Learning approaches, which can help improve understanding and student interest in challenging concepts (Deterding et al., 2011).

These 25 articles in the "unknown" category, after further analysis, did not mention in detail the topics discussed. It is only generally mentioned in science education. Although several focus materials are applied, 25 entries are labeled as "unknown," which suggests that many game-based learning applications may not have been recorded or are less documented. The variation in application requires further research on the effectiveness and learning activities using games across diverse subject areas. Therefore, additional research is needed to explore the potential of Game-Based Learning in creating more engaging and interactive learning experiences in various fields of science and technology (Ryan & Deci, 2020). The application of the GBL research topics in the research locations is presented in Table 3.

Table 3. Application of GBL in Research Locations

No	Research Setting	Frequency
1	Early Childhood Education	1
2	Primary Education	6
3	Junior High School	7
No	**Research Setting**	**Frequency**
4	Senior High School	3
5	University	13
6	Unknown	32

Table 3 above shows the frequency of GBL applications across different educational levels. The data shows that universities have the highest frequency with 13 applications, followed by Junior High Schools and Primary Schools with 7 and 6 applications, respectively. This suggests that this learning technique is being widely adopted, especially at the higher education level, where students can utilize game interactions and dynamics to deepen their understanding of more complex concepts (Gee, 2003).

Although Game-Based Learning has been widely implemented in higher education, the lower frequencies in Early Childhood Education and Senior High Schools indicate areas that may require more attention in research and practical implementation. Additionally, 32 cases were categorized as "unknown," which may suggest gaps in documentation or the unrecorded use of game-based teaching methods in these regions. This underscores the need for further research on the effectiveness and adoption of these methods in various educational settings (Ke, 2014). Table 4 presents the application of the GBL research topics in types of research.

Table 4. Application of GBL in Designs of Research

No	Research Design	Frequency
1	Quantitative	20
2	Qualitative	13
3	Research and Development	8
4	Action Research	2
5	Literature Review	8
6	Mixed Methods	5
5	Unknown	6

Table 4 shows how Game-Based Learning applications are distributed across different research methodologies. Quantitative studies are the most prevalent, appearing 20 times. Next are 13 qualitative studies, followed by eight studies categorized as research and development (R&D). The prevalence of quantitative research suggests a widespread interest in using statistical methods to evaluate the effectiveness of GBL and provide empirical evidence to bolster the credibility of the findings (Creswell, JW, 2020). Qualitative research is crucial for capturing students' experiences and perceptions.

Conversely, action research and literature reviews appear less frequently, with only two and eight instances, respectively, while mixed-methods research accounts for five studies. These patterns suggest that although GBL has received significant scholarly attention, there are still opportunities for further investigation, particularly through more varied and innovative research designs, in its application in educational settings. The involvement of various types of research has the potential to enrich the existing literature and provide more comprehensive insights into the effectiveness and innovation of the learning (Johnson & Onwuegbuzie, 2004). The applications produced by GBL are shown in Table 5.

Table 5. Applications Produced by GBL

No	Applications Produced by GBL	Frequency
1	Unknown	17
2	Augmented Reality	5
3	Card Game	3
4	Virtual Reality (VR)	3
5	Digital Game-based Learning (DGBL)	2
6	Minecraft Education	2
7	Educational Board Game, The Planet-Dart	1
8	Experimental Science Teaching Program (PEEC)	1
9	Game-Based Learning Environment (GBLE)	1
10	Finding a glycoprotein: H,K-ATPase's instance	1
11	Tic-Tac-Toe	1
12	Immersive Virtual Reality Laboratory Simulations	1
13	A Game-Based Learning Module	1
14	Mobile Learning Games (MLG) and Chemistry Games (MCG) Are Not the Same	1
15	Education Mini-Game	1
16	Quizizz	1
17	Simaula	1
18	Game-Based Science Learning (GBSL)	1
19	ORUN-VR	1
20	Splendor Board Game	1
21	Educational Science Board Games	1
22	Mobile Game-Based Inquiry Learning in Science	1
23	Physics Playground Game	1
24	Model For Inclusive Chemistry Teaching (MiC)	1
25	Augmented Reality Game-based Science Learning (ARGSL)	1
26	Frankenstein by Mary Shelley	1
27	Gamification	1
28	AR-Based Learning Environment: "Beat The Beast"	1
29	Insect Garden VR Game	1
30	Escape Room-based Educational Assessment (EREA)	1
31	Longitudinal Play-Based Learning Intervention	1
32	Two types of participatory simulation games are single-team (SPSG) and multi-team (MPSG)	1
33	Minecraft dan Kodu	1
34	Nikola Tesla Center (NTC)	1
35	Kahoot	1
36	Escape Games	1

Table 5 presents various applications generated through the GBL, highlighting the diversity of tools and methods used to create interactive and enjoyable learning experiences. Augmented reality (AR) is one of the most frequently used applications, appearing in five studies. This reflects its growing integration into science education as a tool to enhance student interest and active participation. Additionally, DGBL and Minecraft Education each have a frequency of 2, reflecting the role of digital games as effective tools in enhancing learning motivation and educational outcomes (Gee, 2003).

The range of applications, such as escape games, virtual reality (VR), and various board games, demonstrates the versatility of game-based learning. It can be adapted to diverse formats and educational contexts, offering educators considerable flexibility. However, the presence of 17 entries categorized as "unknown" suggests that GBL's potential remains largely unexplored in several areas. Future research examining the impact of each application on student comprehension and engagement could inform the development of more innovative and responsive instructional strategies (Hamari et al., 2014).

Several research results presented previously indicate that GBL research is expected to continue to increase in publication in the coming year. This shows that the topic of GBL has been in demand in recent years, especially in science education. Indonesia is the second country that have conducted much research on GBL. This is an opportunity to continue research on this topic. In addition, GBL also has the potential to be published in reputable international journals in quartiles 1 and 2. Several visualization results using VOSviewer show several keywords that were researched in the past year. Future studies might address this topic in further depth. Based on the analysis of the study topics, it can be seen that research in physics or chemistry is more than in biology. This is also an opportunity to apply GBL to study issues that have never been studied before. Likewise, with the research location, research methods, and applications used in GBL, several important findings can be used for further discussion and study in subsequent research.

This research on GBL underlines the importance of integrating technology in education to prepare students to face the challenges of 21st-century learning. Along with the continued development of technology, gamification elements are expected to strengthen modern education. Integrating games into science education can facilitate the integration of theory and practice. This reflects the need to design engaging learning experiences for students, especially in science education, to help improve participation and comprehension of difficult ideas. Integrating games into education not only engages students but also enhances the effectiveness of the educational process. This shows the significant potential of GBL methods in improving educational outcomes in science.

LIMITATIONS

This research is limited because it only uses documents from the Scopus database. It does not use Web of Science, Google Scholar, or other sources. In addition, the documents studied are only from the 2021-2024 publication period.

CONCLUSION

In general, the trend of GBL research continues to grow each year, indicating a sustained interest that may lead to an increase in future publications. Most of the articles on GBL are published in reputable international journals, which contributes to their high citation counts. Notably, Indonesia ranks as the second-highest contributing country in this field, showing increasing national engagement with innovative science education practices. This visualization between GBL and science education also reveals emerging keywords over the past year, indicating areas that are gaining research attention and may warrant further investigation. These findings suggest the importance of continually updating pedagogical approaches to match evolving educational technologies. The analysis results are based on the topic of study, place of research, type of research, and applications used in GBL, providing an overview for further researchers to conduct a more in-depth analysis of these findings. Several benefits of GBL in learning can be used as an alternative for science teachers to increase student involvement, motivation, learning outcomes, and learning effectiveness. The limitation of this study is that it only uses documents from the Scopus database. It does not use databases from Web of Science, Google Scholar, or other

sources. In addition, the documents studied are only from the 2021-2024 publication period. Nonetheless, researchers should consider expanding their data sources beyond Scopus and including a broader range of publication years to enhance future bibliometric studies. This would allow for more robust trend analysis and support a deeper understanding of how GBL evolves across diverse educational contexts.

AUTHOR CONTRIBUTIONS

MM conceptualized the study, formulated the methodology, and led the investigative work. SS, MM, and RA performed the formal analysis. SS, MH, NM, and Q helped visualize the data. MM and RA drafted the initial manuscript, which was reviewed and edited by MH, NM, and Q. SS, and RA were responsible for the visualization, and MM supervised the entire process. All authors have read and approved the final manuscript.

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