JRPM
JURNAL REVIEW
PEMBELAJARAN MATEMATIKA

Gamification in Mathematics Education: A Bibliometric Review of Post-Pandemic Research

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ARTICLE INFO	ABSTRACT
	Gamification in mathematics education has risen post-COVID-19 to improve student engagement and learning. This study explores key trends, influential authors, and leading journals through bibliometric and keyword co-occurrence network analysis of 272 publications (2022–2024) from the ERIC database, using the Boolean search "(gamification OR games) AND (mathematics OR algebra OR geometry OR calculus OR statistics)". Using Biblioshiny for Bibliometrix, the analysis identified 812 authors and 138 journals, with prominent contributors including Erin, Fengfeng, and Ji-Eun Lee. Leading journals, such as Education and Information Technologies and Journal of Computer Assisted Learning, emerged as key sources. Three main keyword clusters were identified: game-based learning in mathematics, development of early mathematical skills, and global educational perspectives. The study highlights trends such as problem-solving and student engagement, while revealing a limited research base on the cognitive and social impacts of gamification, particularly at the secondary level. It concludes with recommendations for future research to address gaps and support broader adoption.

INTRODUCTION

The COVID-19 pandemic has triggered major changes in teaching methods, forcing a rapid transition to online and hybrid learning. This is in line with the findings that the COVID-19 pandemic and the industrial revolution 4.0 have changed the learning process, where digital learning environments have become increasingly important and convenient (Maat and Khalid., 2023). Technologies and innovations such as gamification are starting to

be widely used to increase student engagement in distance learning environments. Game-based Learning (GBL) applications have been shown to have many benefits, including helping to improve the quality of mathematics learning by giving students more opportunities to practice (Maat and Khalid, 2023). In addition, games such as Dragon Box and From Here to There! have also been shown to support students' conceptual understanding of algebra during game technology-based learning (Chan *et al.,* 2023).

Gamification is rooted in the idea of incorporating elements such as point scoring, competition, and interactive challenges into traditional teaching methods to foster a more engaging and immersive learning experience. This pedagogical strategy has been particularly relevant in mathematics education, a subject often perceived as abstract and challenging by students. Through gamification, complex mathematical concepts can be simplified and presented in an accessible manner, promoting not only comprehension but also long-term retention of knowledge (Lozano *et al.,* 2023). Gamification, which involves the application of game elements in non-game contexts, has been identified as an effective method for improving motivation and learning outcomes. Gamification has been shown to provide significant benefits in education, as demonstrated in a study using the game, which improved secondary school students' understanding of mathematical feasibility through a dynamic algebraic notation system (Chan et al., 2023; Chan et al., 2022). In mathematics education, gamification can help students understand abstract concepts through an interactive and fun approach. The interactive elements in gamification allow students to be more actively engaged, which helps students manipulate algebraic expressions to explore mathematical equivalence, resulting in better conceptual understanding compared to traditional methods (Chan *et al.,* 2022).

Prior research has demonstrated how well gamification works to encourage active learning and develop critical thinking and problem-solving abilities. Foundational frameworks for comprehending the workings and advantages of gamification in education were offered by researchers such as Deterding et al. (Deterding *et al.,* 2011) and Hamari et al. (Hamari *et al.,* 2014). But little is known about how these ideas are specifically applied in mathematics education, especially in the post-COVID-19 period when digital tools and virtual learning platforms are more common.

Following the pandemic, interest in gamification research in mathematics education has increased, along with the need to maximize digital learning experiences. During the COVID-19 pandemic, game-based learning such as Dragon Box 12+ has become an

effective tool to support mathematics learning, especially in online and hybrid learning settings. The use of these games has been shown to increase student engagement and mathematics achievement despite challenges caused by educational disruptions during the pandemic (Chan et al., 2023). Much research has focused on the effectiveness, design, and application of gamification in mathematics learning contexts (Jutin and Maat, 2024), but few studies have systematically mapped these trends. Previous studies have shown that educational games not only support algebra learning but also show potential to improve mathematics achievement in general, especially for students with lower baseline achievement (Chan et al., 2023; Chan et al., 2022).

The growing body of research on gamification in mathematics education offers several important benefits for the development of digital learning practices. First, these studies help clarify how game elements can be designed to strengthen students' engagement, motivation, and conceptual understanding, three aspects that are often challenging in mathematics learning. Second, the findings provide educators with evidence-based guidance on selecting or designing game-based tools that align with curriculum needs, especially in online or hybrid learning environments. Finally, by mapping trends, key contributors, and thematic developments in this field, this research helps identify gaps that still need to be addressed, offering direction for future innovations in both mathematics pedagogy and educational technology.

Bibliometric studies help us understand research patterns, identify influential researchers and journals, and uncover relationships between topics within a field of study (Donthu *et al.*, 2021; Chen *et al.,* 2024). In post-pandemic studies, research on gamification in mathematics education increasingly shows important patterns and relationships between topics. For example, recent studies highlight the effectiveness of educational games in supporting students' understanding of mathematical concepts such as equivalence and problem solving (Jantakoon *et al.,* 2024). The other studies not only highlight the effectiveness of gamification but also show the potential to chart broader research directions on how game elements impact mathematics learning (Chan et al., 2023; Chan et al., 2022; Anggriany and Rakhmawati, 2024).

In the context of post-pandemic gamification, a bibliometric analysis offers valuable insights into how the field has evolved, what research priorities have emerged, and where future studies could be directed. Studies such as those by Ke et al. (Ke *et al.,* 2024) and Chan et al. (Chan et al., 2023) reveal that the integration of structured mathematical task-based

gamification can enhance students' engagement in contextual problem solving. This study provides a basis for prioritizing research exploring the design of mathematical experience-based games, relevant to students' needs in the digital and post-pandemic era. In addition, the insights generated from this study contribute to the understanding of how educational technology can be optimized to meet the challenges of learning in hybrid or online settings.

By doing a bibliometric analysis of studies on gamification in mathematics education conducted between 2022 and 2024, this study seeks to close this gap. In order to provide insights into the changing environment of this multidisciplinary subject, the study uses data from the ERIC (Education Resources Information Centre) database to identify the most productive authors, main journals, as well as the relationship between keywords that frequently appear in post-pandemic mathematics education gamification research. The main focus of this research is to answer three research questions (RQ) as follows:

RQ1: Who are the most prolific authors in research on post-pandemic gamification of mathematics education, and their main contributions to this field?

RQ2: Which journals have published the most research on gamification in post-pandemic mathematics education, and what are the distinctive characteristics of the research published in these journals?

RQ3: What keywords appear together most frequently in post-pandemic mathematics education gamification research, and what is the relationship between these keywords?

It is hoped that this study will provide useful guidance for researchers and practitioners who wish to understand the current research landscape and the significant contributions that have been made in the field of post-pandemic mathematics education gamification. This work adds to a better knowledge of how gamification might be successfully incorporated into mathematics education to address current possibilities and problems by mapping trends and identifying research needs.

METHOD

In the era of big data, bibliometric analysis synergistically enables researchers to extract valuable insights from vast volumes of academic literature, revealing trends, patterns, and relationships within research fields (Donthu et al., 2021; Maulidiya and Aziza, 2024). Text mining enhances bibliometric analysis by efficiently extracting patterns and insights from vast textual data (Chen et al., 2024). This study employed bibliometric analysis to explore the research landscape of gamification in mathematics education from 2022 to 2024.

Figure 1. Research Procedure (Maulidiya and Aziza)

Figure 1 illustrates the overall bibliometric analysis workflow conducted in this study, starting with defining the research problem and determining the objectives to be achieved. This process begins with identifying relevant literature through the ERIC database, followed by organizing and managing the collected references using Zotero. Once the data is systematically organized, the next step is to extract key bibliometric features using Bibliometrix and its Biblioshiny interface. The workflow concludes with performance analysis and co-word analysis, which are used to map research trends, identify influential contributors, and uncover relationships between key themes in gamification research in mathematics education.

The primary source of data was the ERIC (Education Resources Information Center) database, chosen for its extensive coverage and reliability in the field of education research. The search was conducted using Boolean keywords "(gamification OR game) AND (mathematics OR algebra OR geometry OR calculus OR statistics)" with publication years restricted to 2022–2024. The collected articles were downloaded and stored in digital formats, including .nbib (National Library of Medicine Bibliographic) files, and managed systematically using Zotero. This reference management software facilitated data organization, enabling the classification and tagging of articles and the extraction of bibliographic metadata, such as titles, authors, publication years, journal names, and abstracts. Key features from the articles were then prepared for analysis. These features included keywords, author names, journal titles, publication years, and institutional affiliations. The cleaned data were formatted into BibTeX files, suitable for bibliometric analysis. In total, the study analyzed 272 relevant publications sourced from 138 different outlets and contributed by 812 authors.

The analytical process was carried out using Biblioshiny for Bibliometrix, an R-based web interface that supports a systematic workflow for conducting bibliometric analysis. The procedure began with importing the cleaned BibTeX dataset into Biblioshiny, followed by descriptive performance analysis, which examined publication growth, author productivity, collaboration patterns, and source impact using indicators such as total publications (TP),

citations, h-index, and g-index. Next, source analysis was conducted to identify the most influential journals by evaluating Bradford's Law distribution and source impact metrics.

Furthermore, the study employed network-based analytical techniques, including co-authorship networks, co-word (keyword) networks, and thematic mapping. Keyword co-occurrence analysis was performed using a minimum frequency threshold, resulting in the generation of a network visualization that grouped frequently co-occurring terms into thematic clusters via Fruchterman–Reingold layout and association normalization. Thematic evolution analysis was also used to trace how research themes shifted during 2022–2024. Through these combined techniques, the bibliometric analysis provided a comprehensive mapping of the research landscape by identifying dominant research themes, emerging topics, influential authors, and core publication sources within the domain of gamification in mathematics education.

RESULTS AND DISCUSSION

Most Influential Researchers in Gamification in Mathematics Education

The bibliometric analysis identified 812 authors contributing to research on gamification in mathematics education post-COVID-19. Key authors' contributions throughout the 2022–2024 period show a variety of publication patterns, according to the "Top Seven Relevant Authors' Production Over Time" graph (Figure 2). Among the most prolific contributors, authors such as Erin Ottmar, Jenny Yun-Chen Chan, Fengfeng Ke, Yuejuan Pan, Chih-Pu Dai, Ji-Eun Lee, and John Russo have significantly shaped the discourse in this area. They published at least four articles between 2022-2024. A detailed review of their contributions, as well as insights from additional researchers, highlights the breadth and depth of research.
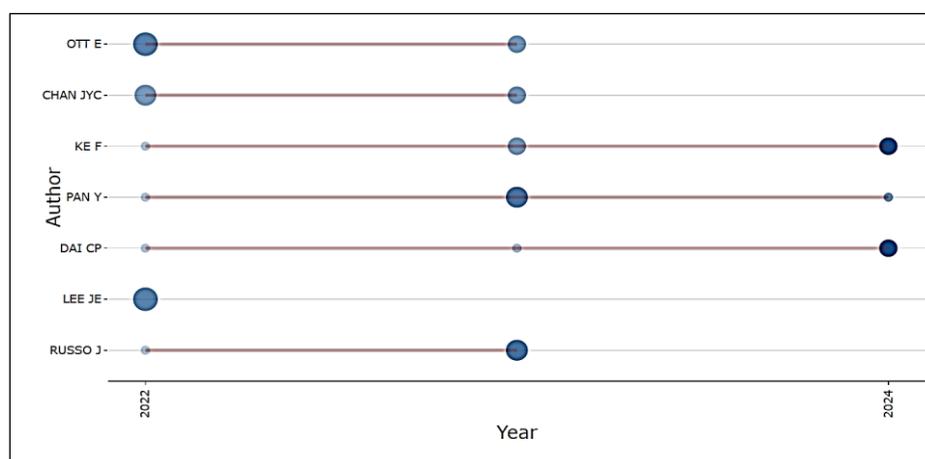

Figure 2. Relevant Author's Production Over Time

Erin Ottmar stands out with six articles, consistently publishing significant work each year, as reflected by the larger circle sizes in the visualised data. This highlights her pivotal role in advancing research, particularly in leveraging game-based technologies to enhance mathematical understanding. For example, Ottmar's 2023 article, "Examining Shifts in Conceptual Knowledge, Procedural Knowledge, and Procedural Flexibility in the Context of Two Game-Based Technologies," explores how game-based tools can improve students' conceptual understanding and procedural adaptability (Chan et al., 2023).

Similarly, Ji-Eun Lee, with four articles, has maintained a steady output of impactful research, focusing on designing effective game mechanics for educational contexts. Authors like Jenny Yun-Chen Chan and Yuejuan Pan have each contributed three articles, with a particular focus on how game-based learning environments influence students' performance and perceived engagement. Pan's 2023 study, "Effects of Game-Based Learning Supports on Students' Performance and Perceived Game Flow," emphasizes the interplay between educational supports and students' game flow experience, highlighting the importance of integrating pedagogical and design elements in gamification (Pan, 2023).

Notably, Chih-Pu Dai and Fengfeng Ke have explored the application of game-based learning to enhance applied problem-solving skills. Ke's 2024 article, "Using Mathematizing Supports for Applied Problem-Solving in a Game-Based Learning Environment," underscores the role of embedded supports in fostering mathematical reasoning within gamified contexts (Ke, 2024).

Additionally, John Russo has made significant contributions by examining game mechanics in classroom settings. His 2023 work, "Unpacking Game Mechanics: Five Types of Whole-Class Mathematical Games," provides practical insights into integrating diverse game mechanics into classroom instruction, enriching the teaching and learning dynamic (Russo, 2023).

The diversity in publication patterns and thematic focuses among these researchers reflects a dynamic and evolving field. The analysis highlights consistent contributors who have laid the groundwork for gamification research and emerging scholars who are exploring new intersections of pedagogy and game-based learning. Such insights not only map the current research landscape but also offer valuable directions for future collaborations and innovations in gamification for mathematics education. This exploration of influential researchers underscores the collective effort driving advancements in gamification. The findings provide a foundation for identifying potential collaborators and leveraging existing

knowledge to address emerging challenges and opportunities in the post-pandemic educational landscape.

Leading Journals in Gamification in Mathematics Education Research

The bibliometric analysis revealed a diverse array of journals contributing to the burgeoning field of gamification in mathematics education, particularly in the post-pandemic era. However, several journals emerged as particularly influential and prolific in publishing research on this topic. To address RQ2, the analysis highlighted 138 distinct sources publishing research on this topic.

Table 1. Most Relevant Sources

No	Sources	Total articles	Country	H-Index	Quartiles
1.	Education and Information Technologies	14	United States	76	Q1
2.	International Journal of Mathematical Education in Science and Technology	9	England	42	Q2
3.	Journal of Computer Assisted Learning	9	England	114	Q1
4.	Primus	8	England	25	Q3
5.	Interactive Learning Environments	7	England	68	Q1
6.	Educational Technology Research and Development	5	United States	109	Q1
7.	Journal of Educational Computing Research	5	United States	76	Q1

Education and Information Technologies emerged as the most prolific journal, with 14 articles published. Based in the United States, this journal holds an impressive H-Index of 76 and is ranked in the highest quartile (Q1), underscoring its reputation as a leading platform for educational technology research. Its prominence in this analysis indicates its central role in bridging technology and pedagogy, making it a primary outlet for studies on gamification.

Following closely, the International Journal of Mathematical Education in Science and Technology and the Journal of Computer Assisted Learning contributed nine articles each. The International Journal of Mathematical Education in Science and Technology, published in the United Kingdom, focuses on mathematical education and holds an H-Index of 42. Although ranked in Q2, its contributions signal its significant visibility and relevance within mathematics education research. On the other hand, the Journal of Computer Assisted Learning, also based in the United Kingdom, boasts an H-Index of 114 and a Q1 ranking, reflecting its strong influence and high-quality contributions to research involving technology integration in education.

A broader analysis of journal rankings revealed that Q1 journals dominated the publication landscape, indicating a strong preference for disseminating gamification research

in highly reputable and impactful outlets. This trend emphasizes the robust academic interest and the perceived value of gamification studies within top-tier journals.

Geographically, the analysis identified the United States and the United Kingdom as the primary hubs for publications in this field. These countries host the leading journals, further reinforcing their roles as centers of innovation and thought leadership in educational research. These findings provide valuable insights for researchers aiming to contribute to the field of gamification in mathematics education. Understanding the leading journals and their attributes can guide researchers in selecting appropriate outlets for their work, ensuring greater visibility and impact within the academic community (Donthu et al., 2021). Furthermore, this analysis highlights the strategic importance of targeting journals with established reputations to maximize the dissemination and influence of future research in this dynamic field.

Research on gamification in mathematics education after the COVID-19 pandemic shows a clear upward trend, supported by contributions from a wide range of scholars and publication outlets. Influential researchers such as Erin Ottmar, Jenny Yun-Chen Chan, Fengfeng Ke, and Ji-Eun Lee have played an important role in advancing discussions on the use of game-based technologies to strengthen students' mathematical understanding. Their studies highlight how game mechanics, learning supports, and interactive digital environments can meaningfully enhance student engagement and improve learning outcomes in mathematics.

In parallel, several leading journals such as *Education and Information Technologies*, *Journal of Computer Assisted Learning*, and the *International Journal of Mathematical Education in Science and Technology* have become key platforms for disseminating research in this domain. Most of these influential journals are based in the United States and the United Kingdom, reflecting both countries' substantial contributions to the development and spread of gamification research in mathematics education.

While the overall growth indicates strong academic interest, the existing literature also reveals several areas that remain underexplored. These include limited attention to the cognitive and social dimensions of gamified learning, as well as the relatively small number of studies focusing on secondary-level mathematics. These gaps highlight the need for further exploration and provide important directions for future research.

Identifying Key Research Themes through Keyword Analysis

This study uses keyword plus, which is an identifier or descriptor from the ERIC

database, to identify the main themes in the research through keyword analysis based on co-occurrence networks. With this approach, researchers can analyze the relationship between keywords that often appear together in relevant publications (Donthu et al., 2021). Through the co-occurrence network (Figure 3), dominant themes in literature related to gamification in mathematics learning can be systematically identified. This technique allows the depiction of relationships between concepts that are often discussed in the selected articles, as well as revealing research trends and the most researched topics in the specified period (Donthu et al., 2021).

The keyword co-occurrence network analysis reveals three distinct clusters of keywords, visually represented by different colors in the image. The red cluster centers around game-based learning, educational games, and mathematics instruction, suggesting a strong focus on the use of games and game-like elements to enhance mathematics education. Keywords like mathematics education, student attitudes, and problem-solving further emphasize the pedagogical and cognitive aspects associated with this approach (Ke *et al.,* 2024). Within this cluster, game-based learning and educational games are pivotal keywords, with high betweenness values of 63.280 and 64.652, respectively, indicating their central role in connecting various research topics. These keywords also show high PageRank values (0.060 and 0.057), reflecting their significant impact on the field. Additionally, mathematics instruction and mathematics achievement further reinforce the focus on improving students' mathematical understanding and performance through gamified approaches (Hui and Mahmud, 2023).
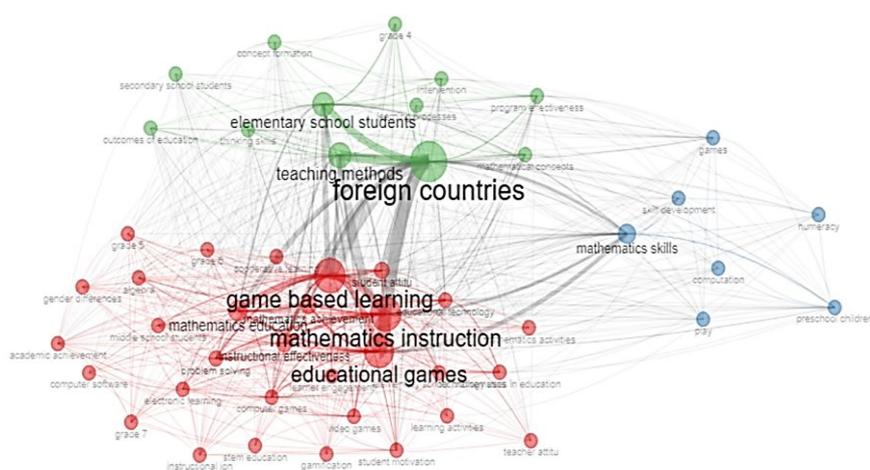

Figure 3. Co-occurrence network of Keyword Plus

The blue cluster, dominated by mathematics skills, games, and preschool children, highlights the focus on developing foundational mathematical skills through game-based

interventions, particularly among young learners. Keywords such as skill development, computation, and numeracy in this cluster indicate an emphasis on fostering basic mathematical abilities and numeracy skills through interactive, game-based methods [20]. Preschool children and elementary school students are also prominent keywords, suggesting that much of the research is concerned with applying gamification to early childhood education and primary school settings (Alotaibi, 2024; Gonzales *et al.,* 2019). The presence of mathematics skills (betweenness: 16.136, PageRank: 0.033) underscores the importance of building core mathematical competencies from an early age, using games to enhance engagement and learning outcomes.

Finally, the green cluster emphasizes broader educational contexts, including foreign countries, teaching methods, and elementary school students, indicating a global perspective on the implementation and effectiveness of game-based learning strategies in diverse educational settings. Keywords like teaching methods, intervention, and program effectiveness show that research is increasingly focused on evaluating the effectiveness of various instructional strategies and game-based programs in different educational systems (Jutin and Maat, 2024). The high betweenness of foreign countries (98.233) and teaching methods (29.442) suggests that a wide range of international studies are exploring the adaptation and impact of gamification in various cultural and educational contexts (Pan, 2023). This cluster reflects an interest in understanding how game-based learning can be integrated across different educational environments and curricula to improve student outcomes.

The following Table 2 presents the clusters identified through the keyword co-occurrence network analysis, highlighting the key research themes in the field of gamification in mathematics education post-COVID-19. Each cluster is characterized by its unique set of keywords, which reflect distinct areas of focus in the research. These clusters represent different aspects of how game-based learning is applied within mathematics education, from foundational skill development to broader educational contexts and global perspectives.

Table 2. Key Research Themes in Gamification in Mathematics Education Based on Keyword Co-Occurrence Network Analysis

Cluster Label	Cluster Keywords	Cluster Description
Game-Based Learning in Mathematics (Red)	Bame-based learning, educational games, mathematics instruction, instructional effectiveness, mathematics achievement, student attitudes, problem solving, educational technology, computer games, video games, learner engagement, technology uses in education, student motivation, middle school students, cooperative learning, electronic learning, grade 6, elementary school mathematics, gamification	Focuses on the use of games and game-based elements to enhance mathematics education. The keywords in this cluster emphasize the pedagogical and cognitive effects of game-based learning, including its impact on student attitudes, problem-solving skills, and mathematics achievement.
Skill Development in Early Education (Blue)	Mathematics skills, games, preschool children, skill development, play, computation, numeracy, grade 5, grade 6	Highlights the development of foundational mathematical skills through game-based interventions, especially for young learners. It emphasizes the improvement of basic mathematical abilities, such as computation and numeracy, through educational games.
Global Educational Contexts (Green)	Foreign countries, teaching methods, elementary school students, program Effectiveness, thinking skills, mathematical concepts, intervention, outcomes of education, concept formation, secondary school students, grade 4, learning processes	Emphasizes the broader educational context in which game-based Learning is implemented. It focuses on the application and effectiveness of these strategies across different countries and educational systems, exploring various teaching methods and their impact on students at different grade levels.

Overall, the analysis reveals that the key research themes in gamification in mathematics education revolve around improving instructional practices through game-based learning, enhancing foundational mathematical skills, and exploring the global application and effectiveness of these strategies. The identified clusters reflect the diversity of research perspectives, with a clear emphasis on both cognitive and pedagogical aspects of gamification, as well as the practical implementation in different educational settings (Hui and Mahmud, 2023). Based on the keyword co-occurrence network analysis, several conclusions regarding the potential and research gaps in the field of gamification in mathematics education can be drawn.

The keyword co-occurrence network analysis reveals potential and research gaps in the field of gamification in mathematics education. The first cluster (red) highlights the growing interest in applying game-based elements to enhance mathematics education, with further research focused on innovative strategies for implementing games to improve mathematical achievement (Russo, 2023). The second cluster (blue) focuses on developing foundational mathematical skills through game-based interventions, especially for younger learners (Aslan

et al., 2024). The third cluster (green) reflects a global perspective on the implementation and effectiveness of game-based learning, exploring the successes and challenges faced in diverse educational systems worldwide (Pan, 2023).

Despite the focus on mathematical achievement and skills development, there is a noticeable gap in research examining the cognitive and social impacts of game-based learning. Few studies delve into how game-based approaches influence critical thinking, problem-solving skills, or students' ability to apply mathematical knowledge in real-world contexts (Ke et al., 2024). Another gap is the lack of research on game-based learning at the secondary education level, with limited exploration of how it can be applied and tailored to higher levels of mathematics education. Additionally, there is a need for more research on the influence of social and environmental factors, such as teacher roles, peer interactions, and classroom dynamics, on the success of game-based learning. Addressing this gap could offer a more holistic view of how game-based learning affects students beyond academic performance.

CONCLUSION AND RECOMMENDATION

This study mapped the development of gamification research in mathematics education in the post-COVID-19 period (2022–2024) through a comprehensive bibliometric analysis using data from the ERIC database. Three research questions (RQ1, RQ2, and RQ3) guided the investigation, and the findings provided an integrated understanding of the evolving scholarly landscape. The findings show that research productivity continues to grow, with key contributors such as Erin Ottmar, Jenny Yun-Chen Chan, Fengfeng Ke, and Ji-Eun Lee actively shaping the field through studies on game-based technologies and mathematical learning. The analysis shows that leading journals such as Education and Information Technologies, Journal of Computer Assisted Learning, and the International Journal of Mathematical Education in Science and Technology serve as key platforms for disseminating gamification-related studies. These journals, primarily based in the United States and the United Kingdom, play an influential role in advancing the field, reflecting strong global interest in integrating digital tools into mathematics instruction. Keyword co-occurrence analysis further revealed three dominant research themes: game-based learning in mathematics, foundational skill development in early education, and global educational perspectives on gamification implementation.

Overall, this study highlights the growing importance of gamification in supporting

engagement, conceptual understanding, and performance in mathematics learning, while also exposing research gaps concerning cognitive impacts, secondary-level applications, and contextual factors in classroom implementation. Future research is recommended to explore these gaps more deeply, expand comparative studies across educational systems, and develop evidence-based design principles for game-enhanced mathematics instruction that align with diverse student needs in digital and hybrid learning environments.

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