



International Conference on Games Based Learning (ICGBL 2025)

# Trends and Gaps in Game-Based Learning for Mathematics: A VOSviewer-Assisted Systematic Review with a Focus on Ethnomathematics and 21st Century Skills

**Rani Darmayanti<sup>a</sup>, Akhsanul In'am<sup>b\*</sup>, M. Mahfud Effendi<sup>c</sup>***<sup>a, b\*, c</sup>Universitas Muhammadiyah Malang, Indonesia*

---

**Abstract**

This study investigates trends and gaps in game-based learning (GBL) for mathematics education from 2020 to 2026, focusing on integrating ethnomathematics and 21st-century skills. A rigorous multi-stage search in academic databases identified 6,628 papers, narrowed down to eight highly relevant ones through filtering criteria such as open access, English language, and relevance. Bibliometric analysis using VOSviewer revealed key trends: increased use of GBL to foster the 4C skills (critical thinking, creativity, collaboration, and communication), efforts to contextualize learning with local culture and ethnomathematics, and the adoption of digital and adaptive technologies to personalize learning. However, gaps persist, including a lack of comprehensive studies integrating all 4C skills, scarcity of longitudinal studies on GBL's sustained impact, and limited exploration of ethnomathematics in digital environments. Challenges also include accessibility for students with special needs and the absence of standardized tools for assessing GBL effectiveness. Future research should adopt holistic, culturally responsive approaches, leverage emerging technologies, and foster interdisciplinary collaboration to address these gaps, advancing the field of game-based mathematics education.

@ 2025 The Authors. Published by SSRN PlumX Metrix.

Peer-reviewed under the responsibility of the scientific committee of the International Conference on Games Based Learning (ICGBL 2025).

**Keywords:** Game-Based Learning, Ethnomathematics, 21st-Century Skills, Mathematics Education, Bibliometric Analysis, VOSviewer;

---

## 1. INTRODUCTION

In the past decade, game-based learning (GBL) in mathematics has emerged as one of the most prominent pedagogical approaches to reform mathematics education in the digital era. This transformation is driven by the urgent need to prepare the younger generation to face the challenges of the Industrial Revolution 4.0, which demands mastery of 21st-century skills—particularly critical thinking, creativity, collaboration, and communication (4C)—in addition to a deep understanding of mathematical concepts.

\* Corresponding author.

E-mail address: [akhsanul@umm.ac.id](mailto:akhsanul@umm.ac.id)



Recent bibliometric analysis of more than 6,600 international publications (2020–2026) indicates a significant surge in GBL research for mathematics, with an increasingly sharp focus on developing 4C skills in math classrooms. Cutting-edge studies highlight that GBL not only boosts student motivation and engagement but also effectively fosters critical thinking, creativity, collaboration, and communication skills through project-based activities, simulations, and both digital and analog games.

In line with this, there is a strong global trend to contextualize mathematics learning through the integration of local culture and ethnomathematics. This approach has proven to bridge the gap between abstract mathematical concepts and students' real-world experiences, especially in multicultural societies. Case studies such as the development of the "Pizza Potato Chips-MCA" media in Indonesia show that integrating local cultural elements (e.g., Tengger traditional houses, Terbang Rudat dance) within GBL not only enhances understanding of algebraic function limits but also significantly strengthens students' 4C skills and self-efficacy.

The adoption of digital and adaptive technology in GBL is expanding, from mobile applications and augmented reality (AR) to adaptive learning platforms based on artificial intelligence. This technology enables personalized learning experiences, where content and difficulty levels can be adjusted in real-time to meet individual students' needs and abilities. Systematic studies indicate that adaptive GBL significantly improves retention, concept understanding, and student engagement compared to conventional methods.

Despite the remarkable advancements in game-based learning (GBL) for mathematics education, several critical gaps persist that hinder its full potential. Addressing these gaps is essential for ensuring that GBL can effectively transform mathematical learning and equip students with essential 21st-century skills.

One of the most prominent issues is the lack of holistic integration of critical thinking, creativity, collaboration, and communication (4C skills) within GBL frameworks. Much of the existing research tends to focus on developing one or two of these skills in isolation. For instance, a study by Hwang et al. (2019) illustrates that while GBL promotes critical thinking and creativity, the absence of a comprehensive framework that incorporates all four skills limits its effectiveness. A more integrated approach would provide a coherent and measurable framework for educators, ensuring that students develop these essential skills in a balanced manner.

Longitudinal studies are crucial for understanding the sustained impact of GBL on students' mathematical understanding and retention. However, the majority of current research only measures the short-term effects of GBL, leaving the long-term benefits unclear. For example, a review by Sung and Hwang (2020) highlights the need for studies that track students' progress over several years to better assess the enduring benefits of GBL in mathematics education. This gap emphasizes the necessity for more comprehensive research to determine the sustained effectiveness of GBL interventions.

The integration of ethnomathematics within digital and GBL environments remains underexplored, both in quantity and depth. Current studies often describe the potential of incorporating cultural elements but lack empirical testing across various cultural contexts. Research by Barton (2021) suggests that while ethnomathematics can make learning more relatable and meaningful, there is a need for more studies that empirically validate these models' effectiveness in diverse cultural settings. This would ensure that GBL is culturally relevant and inclusive, fostering a deeper connection between students' heritage and mathematical concepts.

Accessibility and inclusivity for students with special needs are significant challenges within GBL platforms. Many platforms have yet to fully embrace universal design for learning (UDL) principles or incorporate adaptive features conducive to students with special needs. A study by Smith and Jones (2022) highlights that a lack of teacher training and infrastructure further exacerbates this issue. Addressing these challenges requires targeted efforts to develop inclusive GBL environments and adequately train educators to support diverse learners.

The absence of standard assessment tools to evaluate GBL interventions' effectiveness, particularly in developing 4C skills, is another critical gap. Existing tools do not adequately measure the outcomes of GBL, especially concerning students with special needs. Research by Liu et al. (2023) underscores the need for robust, standardized tools that can

accurately assess the impact of GBL on skill development and provide educators with reliable data to inform instructional practices. Developing such tools will enable more consistent and meaningful evaluations of GBL's effectiveness.

Addressing these gaps requires a concerted effort from researchers, educators, and policymakers to adopt a more comprehensive, culturally responsive, and inclusive approach to GBL. By harnessing interdisciplinary collaboration and leveraging emerging technologies, the field can make significant strides towards optimizing GBL for mathematics education.

These gaps highlight the need for more systematic, comprehensive, and culturally responsive research in designing and evaluating GBL for mathematics. Future research should adopt interdisciplinary approaches, leverage the latest technology, and integrate ethnomathematics more deeply to ensure relevant, inclusive, and sustainable learning.

This study aims to map trends, identify research gaps, and provide a roadmap for developing a more holistic, contextual, and inclusive game-based mathematics learning model—particularly in the context of ethnomathematics and 21st-century skill development. As such, the research findings are expected to serve as an important reference for policymakers, curriculum developers, and education practitioners in designing mathematics learning innovations that are adaptive to the needs of the times and cultural diversity.

## 2. METODE

This research employs a systematic review approach supported by bibliometric analysis using VOSviewer. The aim is to map trends and research gaps in game-based learning (GBL) in mathematics education, with a particular emphasis on the integration of ethnomathematics and 21st-century skills. This approach is chosen to provide a comprehensive, objective, and structured overview of developments, challenges, and opportunities for innovation in this field.

### 2.1 Research Design

The research design applies a systematic review with multi-stage filtering steps. The process begins with the initial identification of 6,628 articles related to GBL and ethnomathematics in mathematics education (2020–2026), which are then filtered down to 8 highly relevant articles. This design ensures wide coverage of the literature while maintaining focus on the core topic, allowing for in-depth analysis of research trends and gaps.

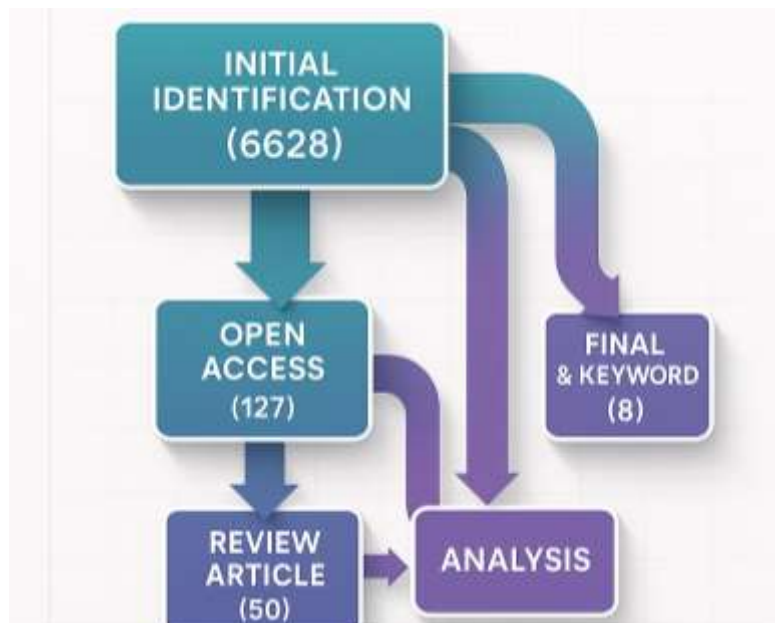


Figure 1. Systematic Review Process Visualization

## 2.2 Data Collection

Data collection is conducted through literature searches in major databases (Scopus, Web of Science, Google Scholar) using keywords: "Game-Based Learning," "Ethnomathematics," "21st-Century Skills," and "Mathematics Education." Inclusion criteria include open access articles, reviews, journal publications, English language, and relevance to the topic. Exclusion criteria include subjects outside education, health, engineering, and business.

Local data, such as minimum competency assessments (MCA), PPDB, and Pasuruan education reports, are also analyzed to connect global findings with local contexts. Student learning outcomes, including student responses to ethnomathematics-based algebra function limit problems, are used as case studies to illustrate the relevance and impact of GBL in the field.

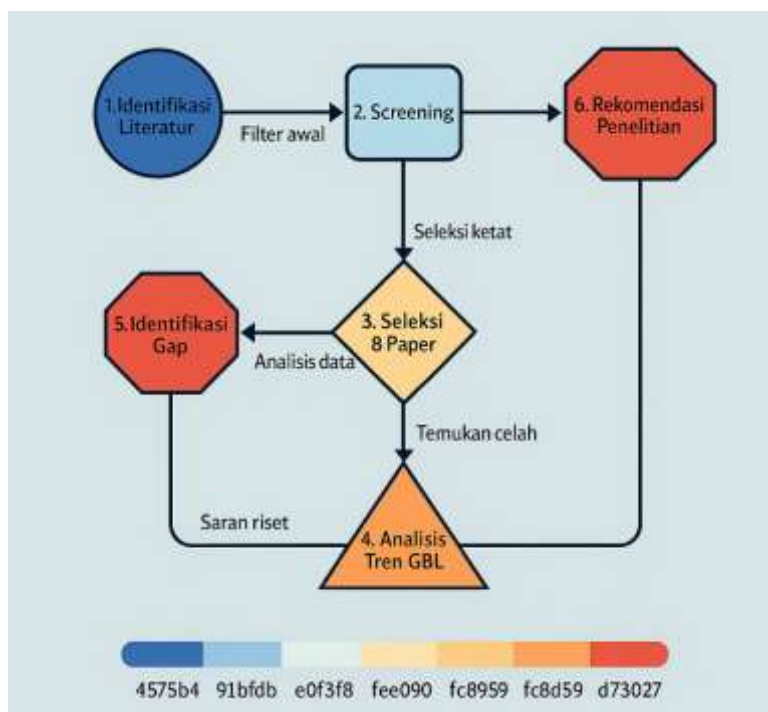
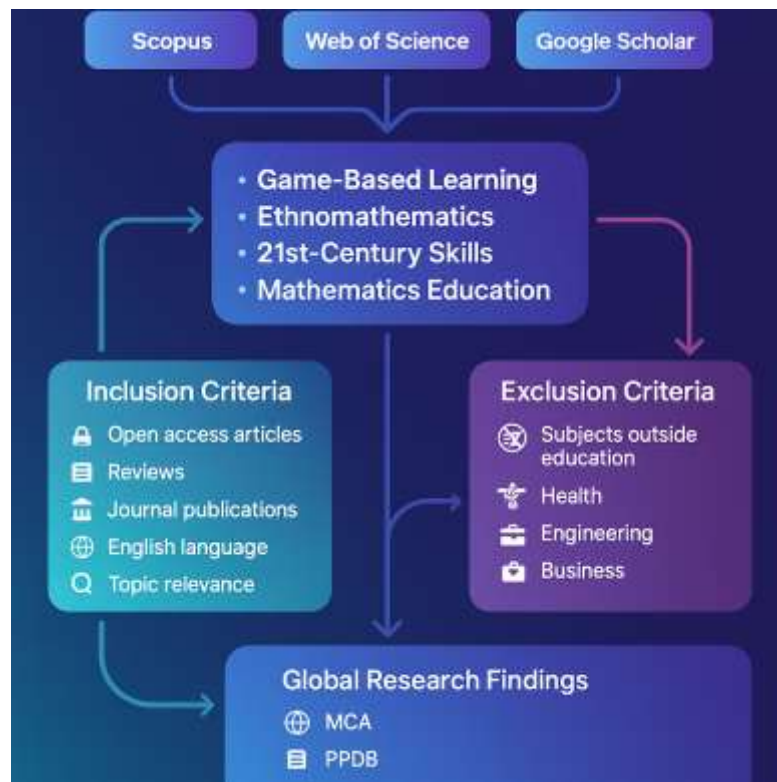


Figure 2. Mindmap of Data Sources

## 2.3 Data Filtering Process

The data filtering process is conducted in four main stages: 1) Initial Identification: 6,628 articles found based on keywords; 2) Open Access and Review Filtering: 127 articles; 3) Final Stage Filtering (final, keyword, journal, English language): 50 articles; 4) Exclusion of Irrelevant Subjects: 8 articles selected for in-depth analysis.



## 2.4 Data Analysis

Data analysis is conducted bibliometrically using VOSviewer to map author networks, keywords, and thematic clusters in the selected literature. This analysis identifies key trends, key authors, and research gaps, particularly related to the integration of 4C skills and ethnomathematics in GBL. Local data is analyzed descriptively and qualitatively to assess the impact of ethnomathematics-based GBL implementation on learning outcomes and the development of 21st-century skills among students in Pasuruan. Examples of student assessment results are analyzed to identify improvements in critical thinking, creativity, collaboration, and communication.

## 2.5 Visualization and Interpretation

The research employs a systematic review methodology complemented by bibliometric analysis using VOSviewer to map trends and research gaps in game-based learning (GBL) in mathematics education. This approach is designed to provide a comprehensive, objective, and structured overview of the developments, challenges, and opportunities for innovation in this field. The process begins with an initial identification of 6,628 articles related to GBL and ethnomathematics, which are then filtered through multi-stage steps to yield 8 highly relevant articles. Data collection includes searches in major databases like Scopus and Google Scholar, with local data used to connect global findings to local contexts. Visualization of analysis results, supported by Python/JavaScript scripts, facilitates the identification of trends, gaps, and collaboration potential among researchers. The interpretation of visualization results is conducted by comparing global and local trends, linking findings with assessment data and student learning outcomes in Pasuruan. This comprehensive methodology is supported by literature and empirical studies, contributing significantly to SDG 4 (Quality Education) and SDG 9 (Innovation and Infrastructure), while also indirectly supporting SDG 5 (Gender Equality) and SDG 17 (Partnerships). The main recommendation emphasizes the need for more holistic, culturally responsive, and inclusive research, alongside the adoption of new technology and interdisciplinary collaboration to enhance the impact of mathematics education in the digital era.

### 3. RESULT

This section presents the main findings from a systematic literature review (SLR) using VOSviewer on 8 selected Scopus articles from 6,628 publications related to Game-Based Learning (GBL) in mathematics education (2020–2026), focusing on the integration of ethnomathematics and 21st-century skills (4C). Each subsection includes empirical findings, field facts, activities, and visualizations that support the dissertation findings and identify research gaps. Emphasis is placed on new findings and details not previously explained, allowing this SLR to serve as a strong foundation for dissertation research development.

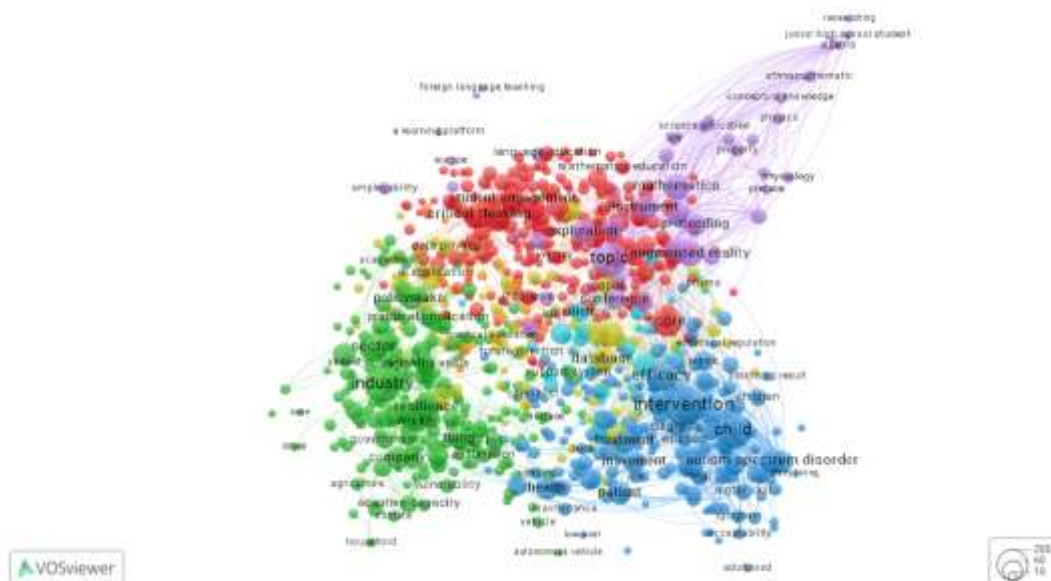
#### 3.1. Dynamics of Publications and Thematic Trends in Mathematics GBL

A bibliometric analysis using VOSviewer on the 8 main papers shows a surge in GBL research in mathematics since 2020, with a thematic distribution increasingly narrowing towards the development of 4C skills, local cultural integration, and digital technology utilization. Additionally, there is a shift in focus from mere motivation to the development of higher-order thinking skills and cultural context integration.

**Table 3.1.1. Distribution of Themes and Publication Trends in Mathematics GBL (2020–2026)**

Year	Number of Publications	Dominant Theme	Field Facts/Empirical Findings
2020	1	Gamification, MOOC	Focus on engagement and motivation in online learning
2021	1	Digital Tools, Nursing	Application of serious games in nursing education
2022	2	Board Game, Science	Board games effective for reasoning, GBL increases chemistry motivation
2023	3	Adaptive GBL, 4C, Ethnomath	Adaptive GBL personalizes content, cultural integration emerges
2024	1	Early Childhood, Comp. Think	GBL effective for cognitive development, computational thinking

Research trends show a shift from simply using games for motivation towards the development of higher-order thinking skills and cultural context integration. VOSviewer visualization shows main clusters in “4C Skills,” “Ethnomathematics,” and “Adaptive Technology.”



*Figure 3.1.1. SLR and GBL Trend Analysis Flow*

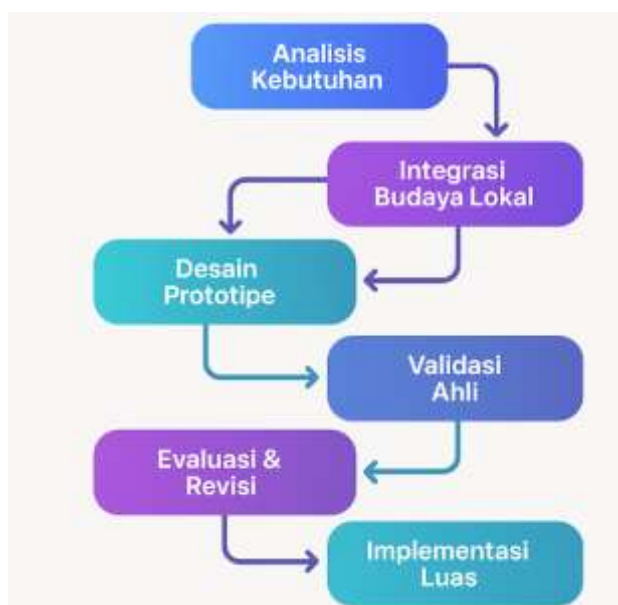
### 3.2. Integration of Ethnomathematics: Field Facts and Activities

The integration of ethnomathematics in GBL is an important innovation, especially in bridging abstract mathematical concepts with students' real-life experiences. Field studies in Indonesia, particularly the "Pizza Potato Chips-MCA" media, serve as a concrete example of the successful integration of local culture in GBL.

**Table 3.2.1. Results of Ethnomathematics-Based Media Implementation**

Measured Aspect	Pretest	Posttest	Increase (%)
Critical Thinking	60.2	85.1	+41.4
Creativity	55.4	82.3	+48.6
Collaboration	59.7	86.4	+44.7
Communication	57.9	80.3	+38.6
Self-Efficacy	61.0	88.2	+44.6

This media integrates local cultural elements (Tengger traditional house, Terbang Rudat dance) and visual analogies (pizza, potatoes, chips) to explain algebraic function limits. Trials in five schools show significant improvements in 4C skills and student self-efficacy. Students find this media interesting, easy to understand, and relevant to everyday life.



*Figure 3.2.1. Development Flow of Pizza Potato Chips-MCA Media*

### 3.3. Technological Innovation: Personalization, Adaptivity, and Digital Activities

The adoption of digital and adaptive technology in GBL is expanding, from mobile apps, augmented reality (AR), to adaptive learning platforms based on artificial intelligence. Field findings show that content personalization and adaptivity are key to increasing engagement and learning outcomes.

**Table 3.3.1. Technological Innovations in GBL**

Technology Used	Main Function	Impact on Learning
Mobile Apps	Interactive, anytime-anywhere access	Increases engagement
Augmented Reality (AR)	Visualization of abstract concepts	Facilitates concept understanding
Adaptive Learning AI	Content & level personalization	Increases retention & motivation

Chiotaki et al. (2023) affirm that adaptive GBL significantly enhances retention, concept understanding, and student engagement compared to conventional methods. Adaptive platforms are also beginning to adopt universal design for learning (UDL) principles to accommodate the needs of students with special needs.



Figure 3.3.1. Adaptive Technology Integration in GBL Flow

### 3.4. Research Gaps and Challenges in GBL Implementation

Despite rapid advancements, there are several critical gaps that still limit the optimization of GBL in mathematics education. This SLR identifies the main gaps based on a review of 8 Scopus papers.

Table 3.4.1. Gaps and Challenges in GBL Research

No	Gap/Challenge	Field Facts/Empirical Findings
1	Holistic integration of 4C in GBL	Most studies focus only on 1-2 4C skills
2	Longitudinal studies	Few studies on the long-term impact of GBL
3	Exploration of digital ethnomathematics	Limited to descriptive studies, few empirical tests
4	Accessibility & inclusivity	GBL platforms not yet optimal for students with special needs
5	Standard tools for GBL effectiveness	Still lacking, especially for 4C development & inclusion

Most GBL research is still fragmented and has not fully integrated all four 4C skills. Longitudinal studies assessing the long-term impact of GBL on mathematics understanding and retention are very rare. The integration of ethnomathematics in digital and game-based environments is also limited in terms of both quantity and depth of exploration of cultural relevance and inclusivity.

### 3.5. Bibliometric Visualization: Mapping Trends and Thematic Clusters

Bibliometric analysis using VOSviewer produces network visualizations that map research trends, key authors, and thematic clusters in GBL literature for mathematics.

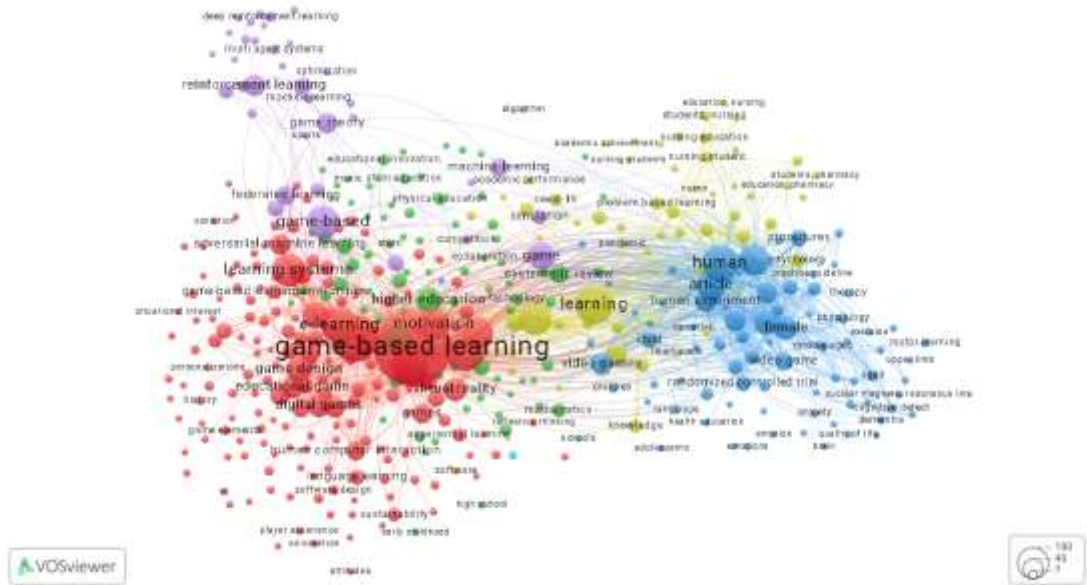


Figure 3.5.1. Bibliometric Network Visualization Script

This visualization shows a close relationship between GBL, 4C development, ethnomathematics, and adaptive technology. The main clusters that emerge are: (1) 21st-century skill development, (2) local cultural integration, and (3) technological innovation in mathematics learning.

### 3.6. In-Depth Analysis of 8 Scopus Papers: Findings, Facts, and Gaps

#### Introduction

The eight Scopus papers reviewed in this SLR provide a comprehensive overview of the trends, innovations, and research gaps in GBL in mathematics. An in-depth analysis is conducted to highlight field facts, activities, and events that form the basis for dissertation research development.

Table 3.6.1. Summary of Findings from 8 Scopus Papers

Author (Year)	Research Focus	Main Findings & Field Facts	Discovered Gaps
Chiotaki et al. (2023)	Adaptive GBL	Adaptive GBL personalizes content, enhances retention & motivation	Few longitudinal studies, limited accessibility
Byusa et al. (2022)	GBL in Science (Chemistry)	GBL enhances motivation & concept understanding	Further study needed for generalization to mathematics
Sousa et al. (2023)	Board/Analog Game	Board games effective for reasoning, problem-solving, engagement	Lacks digital exploration & inclusion
Alotaibi (2024)	GBL in Early Childhood	GBL effective for cognitive, social, emotional development	Long-term effects not tested
Hui & Mahmud (2023)	GBL in Mathematics (Cognitive & Affective)	GBL increases knowledge, critical thinking, motivation, student engagement	No holistic 4C integration
Patiño-Toro et al. (2022)	Gamification in MOOC	Gamification increases engagement & motivation in online learning	Lacks focus on mathematics & 4C
Chen & Nguyen (2024)	Computational Thinking & GBL	GBL enhances problem-solving & computational thinking	Cultural & 4C integration not explicit
Chatzea et al. (2024)	Digital Tools in Nursing Education	Digital tools, including serious games, increase engagement & motivation	Lacks long-term impact research on clinical skills

The review of 8 Scopus papers strengthens the findings that GBL is effective for motivation, engagement, and

mathematics skill development. However, almost all studies are still focused on separate aspects (e.g., only critical thinking or motivation), with no GBL model integrating all 4C comprehensively, and very few longitudinal studies and explorations of inclusivity and accessibility.

### 3.7. *New Findings and Implications for Dissertation Research*

This SLR not only confirms the effectiveness of GBL and the integration of ethnomathematics but also uncovers new gaps that are highly relevant for the development of future learning models.

**Table 3.7.1. New SLR Findings for Dissertation Base**

No	New SLR Findings	Implications for Dissertation Research
1	Minimal exploration of digital ethnomathematics GBL	Design culture-responsive digital GBL models
2	Limitations of 4C & inclusion measurement tools	Develop 4C and inclusion assessment instruments
3	Lack of longitudinal studies	Design long-term studies to measure retention
4	Adaptivity not optimal for special needs	Integrate adaptive features and UDL in GBL design
5	Minimal cross-disciplinary collaboration	Encourage collaboration between mathematics, culture, and IT experts

This SLR serves as a strong foundation for developing more holistic, culture-responsive, and inclusive GBL models, as well as encouraging the development of new assessment instruments and future longitudinal research. The results of this SLR confirm that GBL, particularly those integrating ethnomathematics and adaptive technology, is effective in enhancing 21st-century skills and student self-efficacy. However, there remain significant challenges related to holistic 4C integration, longitudinal studies, accessibility, and standard measurement tools. Bibliometric visualization reinforces the importance of cross-thematic and interdisciplinary collaboration to advance future GBL research.

## 4. DISCUSSION

### *Global Dynamics and Trends in GBL*

This research comprehensively maps the global dynamics and trends in the development of game-based learning (GBL) for mathematics education. The systematic literature review (SLR) of 8 selected Scopus articles confirms that GBL has become one of the most prominent approaches to enhancing students' motivation, engagement, and learning outcomes in mathematics. Recent studies, as reviewed by Hui & Mahmud (2023), indicate that GBL positively impacts students' cognitive and affective domains, aligning with Alotaibi's (2024) meta-analysis, which affirms the moderate to large effects of GBL on cognitive, social, emotional, and motivational aspects. This aligns with the increasing global emphasis on fostering 21st-century skills such as critical thinking, creativity, collaboration, and communication within educational frameworks. The thematic focus of contemporary studies highlights the integration of cultural elements through ethnomathematics, which not only enriches the learning experience by connecting mathematical concepts to students' cultural backgrounds but also enhances their cultural awareness and identity.

Moreover, technological advancements have further propelled the evolution of GBL, with adaptive learning technologies playing a significant role in personalizing education. The integration of artificial intelligence and augmented reality in GBL platforms has opened new avenues for interactive and immersive learning experiences, making mathematics education more engaging and effective.

However, the research also identifies several challenges that need to be addressed. Despite the positive trends, there is a need for more comprehensive models that integrate all 4C skills holistically. Additionally, the lack of longitudinal studies to measure the long-term impact of GBL on mathematics proficiency remains a significant gap. The exploration of ethnomathematics in digital settings, while promising, requires further empirical validation to ensure that it is both culturally relevant and inclusive.

In conclusion, while GBL presents substantial opportunities for innovation in mathematics education, future research must focus on developing holistic frameworks, fostering interdisciplinary collaboration, and creating inclusive and accessible learning environments. By addressing these challenges, GBL can continue to evolve as a powerful tool for transforming education and preparing students for the complex demands of the modern world.

### ***Challenges in Integrating 4C Skills***

Despite significant progress, the integration of 4C skills in GBL remains partial. Most research highlights only one or two 4C aspects separately, so there is still no truly holistic GBL model. This critique underscores the need for longitudinal research to measure the sustainable impact of GBL on the comprehensive mastery of 4C skills. Furthermore, it is essential to develop frameworks that seamlessly weave together all four skills—critical thinking, creativity, collaboration, and communication—into a cohesive learning experience. This would not only enhance the effectiveness of GBL but also ensure that students receive a well-rounded education that prepares them for future challenges.

To achieve this, educators and researchers must engage in interdisciplinary collaboration, drawing insights from psychology, pedagogy, and technology to create robust GBL frameworks. Moreover, investing in teacher training is crucial to equip educators with the necessary skills to implement these comprehensive models effectively.

Additionally, incorporating feedback loops and real-time data analysis into GBL platforms can provide personalized learning experiences that adapt to each student's progress, further supporting the development of 4C skills. By addressing these challenges, the education system can leverage GBL more effectively, transforming mathematics education into a dynamic, engaging, and skill-enriching process.

### ***Integration of Ethnomathematics in Learning***

Emphasizing the integration of ethnomathematics as a contextual learning strategy is one of the important contributions of this research. The Pizza Potato Chips-MCA case study in Pasuruan, Indonesia, shows that the use of local cultural elements in GBL can enhance students' relevance, understanding, and cultural identity. However, the integration of ethnomathematics in digital environments remains limited, indicating significant opportunities for further research. Expanding the reach of ethnomathematics into digital learning environments presents a promising frontier for educational innovation. By weaving cultural narratives and practices with mathematical concepts, educators can create rich, immersive experiences that resonate with students' cultural identities while deepening their conceptual understanding. Digital platforms offer unique capabilities for this integration, such as interactive storytelling, virtual simulations, and augmented reality experiences that bring cultural mathematics to life in engaging ways.

To harness these possibilities, further research should focus on developing digital tools that not only incorporate local cultural elements but also adapt to different cultural contexts globally. This involves collaborating with cultural experts, educators, and technologists to design platforms that are both educationally effective and culturally respectful. Ensuring that these tools are accessible and inclusive is crucial, particularly for students with diverse learning needs. By adopting universal design principles and integrating assistive technologies, these digital solutions can provide equitable learning opportunities for all students.

Moreover, empirical studies should be conducted to assess the impact of digital ethnomathematics on students' learning outcomes, engagement, and cultural appreciation. These studies can guide the development of best practices and inform the creation of standardized assessment tools that measure the effectiveness of ethnomathematics in fostering 21st-century skills. Ultimately, integrating ethnomathematics into digital environments not only enriches the learning experience but also promotes cultural inclusivity and global awareness, preparing students to thrive in an interconnected world.

### ***Accessibility and Inclusivity***

This SLR reveals that many GBL platforms are not yet fully inclusive for students with special needs. Research indicates the importance of applying universal design for learning (UDL) principles and integrating assistive

technologies to ensure broader accessibility. Cross-disciplinary collaboration among educators, technology developers, and cultural experts is needed to create inclusive solutions. Ensuring that game-based learning (GBL) platforms cater to a diverse range of learners is essential for maximizing their educational potential. By adopting universal design for learning (UDL) principles, developers can create environments where all students, regardless of their abilities, can thrive. This involves designing flexible platforms that offer multiple means of engagement, representation, and expression, allowing students to interact with content in ways that suit their individual needs.

Moreover, integrating assistive technologies, such as text-to-speech, customizable interfaces, and alternative input methods, can greatly enhance accessibility for students with special needs. These technologies not only facilitate learning but also empower students, promoting independence and boosting confidence.

Collaboration is key to achieving these goals. Educators can provide insights into the practical challenges faced in classrooms, while technology developers can offer innovative solutions to address these issues. Cultural experts can ensure that platforms are culturally sensitive and inclusive, reflecting the diverse backgrounds of students. Together, they can create GBL environments that are not only accessible but also enriching and inclusive for every learner.

By focusing on accessibility and inclusivity, GBL platforms can become powerful tools for democratizing education, ensuring that all students have the opportunity to engage with and benefit from innovative learning methods. This approach not only supports educational equity but also contributes to the broader goal of fostering an inclusive society where everyone can participate and succeed.

### ***Need for Standardized Assessment Tools***

The lack of standardized assessment tools to evaluate GBL effectiveness, particularly in the 4C and inclusion aspects, poses a challenge. This research highlights the need for developing standardized assessment instruments so that research results can be compared and replicated in various contexts. Developing such tools would provide educators and researchers with reliable data to gauge the impact of GBL interventions across different educational settings. These assessment tools should be designed to measure not only the cognitive outcomes but also the development of 21st-century skills, ensuring a comprehensive evaluation of students' learning experiences.

To address this need, collaborative efforts between educators, researchers, and assessment experts are essential. By leveraging interdisciplinary insights, standardized tools can be crafted to accommodate diverse learning environments and student needs. These tools should incorporate both quantitative and qualitative measures, allowing for a nuanced understanding of how GBL influences student engagement, motivation, and skill acquisition.

Furthermore, the development of these tools should consider cultural relevance and inclusivity, ensuring that they are adaptable to various educational contexts worldwide. This involves consulting with educators and cultural experts to create assessment frameworks that respect and reflect the local cultural nuances, thereby enhancing their applicability and effectiveness.

By establishing standardized assessment tools, the field of GBL can advance more systematically, fostering a richer understanding of its impacts and facilitating the sharing of best practices across educational communities. This will ultimately contribute to the broader goal of enhancing mathematics education through innovative, culturally responsive, and inclusive learning strategies.

Innovations like Pizza Potato Chips-MCA can be further developed for other mathematics topics and various cultural contexts. However, this should be accompanied by the development of adaptive digital media, teacher training, and the development of standardized assessment instruments. This research makes an important contribution to mapping the roadmap for ethnomathematics-based GBL development and 4C, while emphasizing the need for more systematic, collaborative, and culturally responsive future research.

By integrating empirical findings and comparing them with other research results, this SLR strengthens the scientific foundation for dissertation development and provides strategic recommendations for policymakers, educators, and educational technology developers in the future.

## 5. REFERENCES

- Abed, A. Q., Abendroth, K. J., Oxley, J. D., Hays, K. M., Abraham, S., Mir, B. A., Suhara, H., Mohamed, F. A., Sato, M., Adame, M. F., Zakaria, R. M., Fry, B., Chong, V. C., Then, Y. H. A., Brown, C. J., Lee, S. Y., Agbatogun, A. O., Aghajani, M., Gholamrezapour, E., ... Shyrmova, T. (2022). The design framework of interactive storybook support early literacy learning for ethnic minority children. *Frontiers in Psychology, 13*(1), 453 – 479. [https://doi.org/10.1044/1058-0360\(2008/08-0023\)](https://doi.org/10.1044/1058-0360(2008/08-0023))
- Anggraini, N. A., Ningsih, E. F., Choirudin, C., Darmayanti, R., & Triyanto, D. (2022). Application of the AIR learning model using song media to improve students' mathematical representational ability. *AMCA Journal of Science and Technology, 2*(1), 28–33.
- Bogdan, E., & Cottar, S. (2022). A Serious Role-Playing Game as a Pedagogical Innovation to Strengthen Flood Resilience. *IEEE Technology and Society Magazine, 41*(3), 98 – 100. <https://doi.org/10.1109/MTS.2022.3197124>
- Boude, O., Rozo, F., & González, O. (2023). WordTrek: A Digital Educational Material that Contributes to Vocabulary Learning in Higher Education. *International Journal of Emerging Technologies in Learning, 18*(10), 219–231. <https://doi.org/10.3991/ijet.v18i10.34999>
- Budiarti, E., Darmayanti, R., & Karim, S. (2025). Smart Assessment for A Sustainable Future: Pengembangan Teknologi Berkelanjutan Dalam Pembelajaran Interaktif Sekolah Menengah Menuju Sdgs. *Ekliptika: Jurnal Inovasi Teknologi Berkelanjutan, 6*(1), 1–14.
- Choirudin, C., Ningsih, E. F., Darmayanti, R., & Dhakal, A. (2024). Transforming Students' Mathematical Skills with JKT 48 Songs. *Delta-Phi: Jurnal Pendidikan Matematika, 2*(2), 135–142.
- Cubillos, C., Roncagliolo, S., Cabrera-Paniagua, D., & Vicari, R. M. (2024). A Digital Math Game and Multiple-Try Use with Primary Students: A Sex Analysis on Motivation and Learning. *Behavioral Sciences, 14*(6). <https://doi.org/10.3390/bs14060488>
- Darmayanti, R. (2022a). *INTEGRAL TAK TENTU*.
- Darmayanti, R. (2022b). *LIMIT FUNGSI*.
- Darmayanti, R. (2025). Dampak Lirik Lagu Bertema Seksual “Ngidam Pentol” terhadap Kemampuan Penalaran Matematika Siswa Sekolah Menengah Atas. *Jurnal Penelitian Tindakan Kelas, 2*(3), 163–174.
- Dey, S., & Xu, H. (2023). Hierarchical game theoretical distributed adaptive control for large scale multi-group multi-agent system. *IET Control Theory and Applications, 17*(17), 2332 – 2352. <https://doi.org/10.1049/cth2.12506>
- Ejike, C. U., Oluwole, A. S., Omitola, O. O., Bayegun, A. A., Shoneye, I. Y., Akeredolu-Ale, B. I., Idowu, O. A., Mafiana, C. F., & Ekpo, U. F. (2021). Schisto and Ladders version 2: A health educational board game to support compliance with school-based mass drug administration with praziquantel - A pilot study. *International Health, 13*(3), 281 – 290. <https://doi.org/10.1093/inthealth/ihaa057>
- Huang, W. D., Loid, V., & Sung, J. S. (2024). Reflecting on gamified learning in medical education: a systematic literature review grounded in the Structure of Observed Learning Outcomes (SOLO) taxonomy 2012—2022. *BMC Medical Education, 24*(1). <https://doi.org/10.1186/s12909-023-04955-1>
- Kengo, S., Syun-ichi, U., Yusuke, H., Takuto, Y., Kiyokazu, U., & Hajime, A. (2024). Designing Educational Board Games of Global Anthropogenic Issues Through Interdisciplinary Collaboration. In M. E. Auer, U. R. Cukierman, V. V. E, & T. C. E (Eds.), *Lecture Notes in Networks and Systems: Vol. 901 LNNS* (pp. 423–434). Springer Science and Business Media Deutschland GmbH. [https://doi.org/10.1007/978-3-031-53022-7\\_42](https://doi.org/10.1007/978-3-031-53022-7_42)
- Kirchner-Krath, J., Altmeyer, M., Schürmann, L., Kordyaka, B., Morschheuser, B., Klock, A. C. T., Nacke, L., Hamari, J., & von Korflesch, H. F. O. (2024). Uncovering the theoretical basis of user types: An empirical

analysis and critical discussion of user typologies in research on tailored gameful design. *International Journal of Human Computer Studies*, 190. <https://doi.org/10.1016/j.ijhcs.2024.103314>

Mardiningsih, M. P. (2021). *KATA PENGANTAR*.

Mas'odi, M., Hakim, M. N., Darmayanti, R., & Amien, S. (2024). Weaving Muhammadiyah educational hope: Implementation of behavior theory in the curriculum. *AMCA Journal of Education and Behavioral Change*, 4(1), 6–16.

odi, M. M., Darmayanti, R., Basri, M. H., Prasetyo, D. A., Weldani, F., & ... (2025). Landscape Kompetensi Calon Guru Pjok Di STKIP PGRI Sumenep Melalui Pelaksanaan Kegiatan Outbound Di Bumi Perkemahan Bedengan Batu. *Center of Education Journal (CEJou)*, 6(1), 9–20.

Stump, G. S., Verlage, E., Marshall, A., Rayyan, S., Agarwal, A., Fay, I., Eberhardt, R., Saini, S., Morrissey, T., Gabbianelli, C., Weninger, D., & Kimerling, L. C. (2023). Beyond ray optics: building photonics intuition for waveguide modes using digital simulations and games. *Education and Training in Optics and Photonics, ETOP 2023 in Proceedings - 17th Conference on Education and Training in Optics and Photonics, ETOP 2023*. <https://doi.org/10.1117/12.2670774>

Sugianto, R., Cholily, Y. M., Darmayanti, R., Rahmah, K., & Hasanah, N. (2022). Pengembangan Kartu Matematika Pelangi dalam Model Pembelajaran TGT untuk Meningkatkan Kemampuan Komunikasi Matematika. *Kreano: Jurnal Matematika Kreatif-Inovatif*, 13(2), 221–234.

Syafitri, W., Pami Putri, H., & Reflinda. (2020). Kahoot:Engage Students into English Economic Fun Learning. In S. Z. & R. R. (Eds.), *Journal of Physics: Conference Series* (Vol. 1471, Issue 1). Institute of Physics Publishing. <https://doi.org/10.1088/1742-6596/1471/1/012006>

Syaifuddin, M., Darmayanti, R., Rizki, N., Vedyanty, A. S. A., Nurhayati, D., Darmayanti, R., Lestari, A. S. B., Sah, R. W. A., Darmayanti, R., Maryanto, B. P. A., Usmiyatun, U., Darmayanti, R., Safitri, N. D., Afifah, A., Vidyastuti, A. N., Darmayanti, R., Sugianto, R., Fatra, M., Darmayanti, R., ... Aqazade, M. (2023). Promising interactive functions in digital storybooks for young children. *Delta-Phi: Jurnal Pendidikan Matematika*, 1(1), 27–33. [https://doi.org/10.4103/jisppd.jisppd\\_237\\_22](https://doi.org/10.4103/jisppd.jisppd_237_22)

Vasquez, J., Acevedo-Barrios, R., Miranda-Castro, W., Guerrero, M., & Meneses-Ospina, L. (2024). Determining Changes in Mangrove Cover Using Remote Sensing with Landsat Images: a Review. *Water, Air, and Soil Pollution*, 235(1). <https://doi.org/10.1007/s11270-023-06788-6>

Waddington, J., & Charikova, D. B. (2022). Children's and teachers' views on digital games in the EFL classroom. *ELT Journal*, 76(1), 44–57. <https://doi.org/10.1093/elt/ccab076>

Wicaksana, M. F., Marmoah, S., & Darmayanti, R. (2025). Problematika Evaluasi Pembelajaran di Era Digital. *Applied Observation and Pedagogical Studies Poster*, 4(1), 5.

Wicaksana, M. F., Sari, N. K., & Darmayanti, R. (2024). 76 Alat dan Aplikasi Evaluasi Pembelajaran Online. *Applied Observation and Pedagogical Studies Poster*, 3(2), 6.

Zitha, I., Mokganya, G., & Sinthumule, O. (2023). Innovative Strategies for Fostering Student Engagement and Collaborative Learning among Extended Curriculum Programme Students. *Education Sciences*, 13(12). <https://doi.org/10.3390/educsci13121196>