Journal of Research and Advances in Mathematics Education

Volume 11, Issue 2, April 2026, pp. 138-154
DOI: 10.23917/jramathedu.v11i2.15463
p-ISSN: 2503-3697, e-ISSN: 2541-2590

Digital game-based learning in mathematics learning with cultural contexts: A systematic literature review

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Citation: Usman, Z. Z., Priatna, N., Juandi, D., & Fitria, T. (2026). Digital game-based learning in mathematics learning with cultural contexts: A systematic literature review. *JRAMathEdu (Journal of Research and Advances in Mathematics Education), 11*(2), 138–154. https://doi.org/10.23917/jramathedu.v11i2.15463

ARTICLE HISTORY:
Received 8 January 2026
Revised 29 March 2026
Accepted 15 April 2026
Published 30 April 2026

KEYWORDS:
Digital game-based learning
Cultural context
Mathematics learning
Research exploration
Systematic literature review

ABSTRACT

The increasing integration of digital technologies into education has encouraged the use of Digital Game-Based Learning (DGBL) to enhance students' engagement and mathematical understanding; however, research on incorporating cultural contexts into DGBL for mathematics learning remains fragmented and lacks a comprehensive synthesis. This study aims to systematically review existing literature on culturally contextualized DGBL in mathematics education by identifying dominant research designs, participant characteristics, mathematical content, cultural representations, learning outcomes, and future research directions. A systematic literature review was conducted following the PRISMA framework using data retrieved from the Scopus database with the keywords "digital game-based learning" AND "cultural" AND "mathematics". Of the 153 initially identified documents, 14 studies met the inclusion and quality assessment criteria and were analyzed through content analysis. The results of the study are the most widely used types of qualitative and experimental research, with the research subjects being elementary and junior high school students. The research instruments that are widely used are interviews, questionnaires, observations and tests. Mathematics material in elementary schools is widely used in this research, with the cultural context being the culture and identity of students. Most of the media used is digital games. Most studies reported positive effects on students' attitudes, engagement, learning experiences, and learning processes. This review contributes a comprehensive overview of methodological and thematic trends in culturally contextualized DGBL research and highlights the need for theoretically grounded, culturally meaningful, and pedagogically robust game-based learning environments that support diverse learners and more advanced mathematical learning objectives.

INTRODUCTION

Mathematics is a universal science that serves as the foundation for many scientific disciplines (Kilpatrick et al., 2001). It plays a significant role in advancing society and the economic prosperity of individuals, as well as fostering science and technological development in a country (Saal et al., 2024). Mathematics learning is therefore essential for students to develop problem-solving abilities and analytical thinking skills that are useful in everyday life (Herawaty et al., 2020; Kenedi et al., 2019).

Even though mathematics is very important, in reality, mathematics education always faces challenges related to student engagement, conceptual understanding, and the application of meaningful mathematical ideas in authentic situations (Raj Acharya, 2017). Numerous educational systems report that many students perceive mathematics as abstract, difficult, and disconnected from their daily experiences, which ultimately reduces motivation and participation in classroom activities (Khoo et al., 2024; Mbalekwa et al., 2024). This situation became even more pronounced during and after the COVID-19 pandemic, when the intensive use of digital technology and mobile

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devices significantly changed students' learning habits and attention patterns (Tyagi et al., 2021). Students became more accustomed to interactive digital environments and entertainment-oriented applications, while conventional instructional approaches were often perceived as monotonous and less stimulating (Anggraini & Dewi, 2022; Nadeem et al., 2023). This situation has encouraged educators and researchers to seek instructional approaches capable of transforming students' digital engagement into meaningful learning experiences.

Interest is the greatest motivation for students to study, and the most effective way to study is through games that direct students to study so that students feel that studying is as fun as playing (Chih-Hsiao & Yen, 2017). The idea that using games for fun while learning can increase motivation and spark interest during learning has been put forward by researchers as a viable and effective teaching method (Lee & Hao, 2015). Not only games, but the utilization of technology in teaching can also increase students' interest as it engages students in learning, provides learning experiences, improves conceptual understanding, and fosters mathematical thinking (Dai et al., 2022; Hwang & Wu, 2012).

Digital Game-Based Learning (DGBL) Model is a model that integrates elements of gameplay, interactivity, and digital technology into the learning process (Saal et al., 2024). Research demonstrates that well-designed digital games can support exploration, problem solving, and experimentation in mathematics learning environments (Byun & Joung, 2018; Dai et al., 2022). The experts argue that digital games promote persistence and intrinsic motivation because they provide immediate feedback and adaptive learning pathways (Plass et al., 2015). Findings from meta-analytic research show positive effects of digital games on mathematics achievement and students' attitudes toward the subject (Byun & Joung, 2018). Cognitive engagement increases when learners manipulate mathematical objects within game environments that simulate real-world scenarios (Wang et al., 2018). Broader adoption of DGBL in mathematics classrooms reflects recognition that digital technologies can transform passive learning experiences into active knowledge construction processes (Hwa, 2018).

Although DGBL has shown considerable potential in mathematics learning, many existing digital mathematics games are still poorly connected to students' cultural and social realities, leading students to perceive mathematical concepts as unrelated to everyday life (Yang et al., 2025). Several studies have noted that traditional educational games often fail to align with students' cultural and personal contexts, leading to inactivity or unintended learning outcomes (Wisittanawat & Gresalfi, 2020). This limitation is important because mathematics is closely related to human culture and daily life (Risdiyanti & Prahmana, 2021). The construction of knowledge through culture can be obtained from cultural tools, symbols, social interactions, and contextual experiences. Consequently, mathematics learning becomes more meaningful when instructional activities connect mathematical concepts to familiar cultural practices, community experiences, local knowledge systems, and students' identities (Hendriyanto et al., 2023; L. Li, 2021).

In this study, the term cultural context refers to learning situations, narratives, representations, symbols, practices, identities, or environments that are directly associated with the social and cultural experiences of learners. This definition includes ethnomathematical elements, indigenous or local knowledge, local language use, culturally relevant narratives, student identity representation, historical-cultural practices, and everyday cultural activities that shape learners' understanding of mathematics. Researchers exploring culturally contextualized digital learning environments report improved motivation and stronger emotional connections to the learning process (Gaddam et al., 2018). In addition, culture also significantly influences one's choice of technology and technology-mediated learning, so culture must be taken into account when designing educational digital games (Park & Wen, 2016). So, it can be concluded that educational innovations combining cultural relevance and digital technologies are a promising direction for contemporary mathematics education.

Several previous reviews have examined Digital Game-Based Learning from different perspectives, including learning achievement, engagement, motivation, technological design, and interaction patterns in educational games (Byun & Joung, 2018; Hwa, 2018; Plass et al., 2015). Other studies have explored how learning using cultural materials can increase students' learning

motivation and facilitate students' understanding of a lesson (Hendriyanto et al., 2023). However, limited attention has been given specifically to the intersection between DGBL, cultural context, and mathematics learning. Existing studies remain fragmented across disciplines and educational levels, especially at the elementary education (Dan et al., 2024). In addition, many previous reviews have pointed to a lack of attention to the integration of cultural context in mathematics-focused digital games (Hwa, 2018). Previous reviews have rarely identified what mathematics topics are taught, what research methodologies dominate the field, what variables are frequently studied, and what forms of cultural integration are most commonly applied in DGBL mathematics research. This fragmentation creates difficulties in identifying consistent patterns, methodological trends, research gaps, and future directions for the development of culturally contextualized digital mathematics learning.

Another unresolved issue concerns the extent to which current DGBL research in mathematics learning. Many studies report that DGBL can have a positive impact on various aspects of student learning, such as increased knowledge, conceptual and cognitive skills, affective and motivational outcomes, and behavioral transformation outcomes, but few studies explain how cultural integration supports this (Dan et al., 2024). Similarly, there remains limited discussion regarding which educational levels, mathematical materials, and cultural dimensions are most frequently represented in existing studies. The absence of a comprehensive synthesis makes it difficult for researchers, teachers, and educational designers to identify which areas have been extensively explored and which areas still require further investigation. Therefore, a systematic literature review is necessary to map current research trends, identify dominant methodological approaches, examine forms of cultural integration within DGBL mathematics learning, and evaluate the directions suggested for future research (Augustine & Lucas, 2026).

Based on the information above, this study aims to systematically review research on Digital Game-Based Learning with cultural contexts in mathematics learning. Specifically, this review addresses the following research questions:

RQ1. What types of research designs are most commonly used in studies on DGBL with cultural contexts in mathematics learning?
RQ2. What research subjects, educational levels, and research instruments are most frequently involved in the studies?
RQ3. What mathematical materials and forms of cultural context are integrated into DGBL mathematics learning?
RQ4. What variables, learning media, and educational outcomes are most frequently investigated in the reviewed studies?
RQ5. What limitations and future research directions are identified in studies related to DGBL with cultural contexts in mathematics learning?

This study is expected to contribute theoretically and practically to the development of mathematics learning research by providing a clearer understanding of current trends, conceptual patterns, and methodological tendencies in culturally contextualized DGBL research. The findings may also support researchers, educators, instructional designers, and policymakers in identifying opportunities for developing more meaningful, culturally responsive, and pedagogically effective digital mathematics learning environments.

METHODS

This type of research is a systematic literature review using the content analysis method as data analysis. The use of this method is because it can offer a comprehensive review of earlier works on the generic and specific issues considered in the research (Lune & Berg, 2017). The reference in compiling a systematic review in this study is the PRISMA method with four stages (Moher et al., 2010) which is shown in Figure 1.

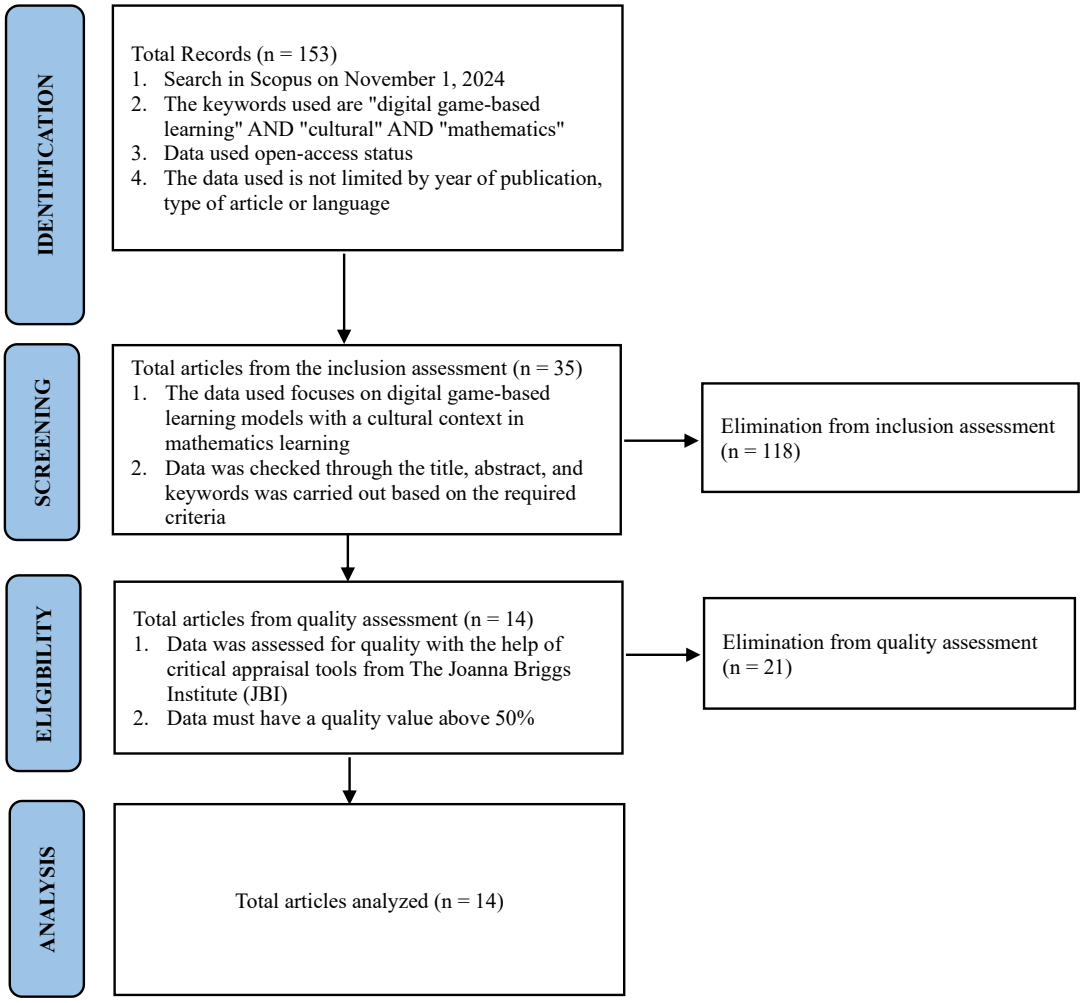

Figure 1. Research stages process

The first stage in PRISMA is identification. The identification stage aimed to collect relevant studies associated with DGBL, cultural contexts, and mathematics learning. The literature search was conducted through the Scopus database on November 1, 2024. The reason why only Scopus was used as the database in this study is that Scopus is the largest curated abstract and citation database, while ensuring that only high-quality data is indexed through rigorous content selection and re-evaluation (Baas et al., 2020). Scopus indexes a vast range of peer-reviewed journals, conference proceedings, and other scholarly content across multiple disciplines, making it a robust resource for SLR (Valente et al., 2022). The database is widely recognized in systematic literature review studies because it provides broad international coverage and reliable bibliometric information. Although additional databases such as Web of Science or ERIC may provide complementary sources, Scopus was considered sufficient for this review because the objective of the study was to map high-quality international publications related to DGBL with cultural contexts in mathematics learning.

In order for the research to be directed towards the objective, the keywords used in the search are "digital game-based learning" AND "cultural" AND "mathematics". The search process was conducted without restrictions on publication year to capture the historical development of the topic comprehensively. Only peer-reviewed journal articles and conference proceedings published in English were included to ensure academic quality and consistency of interpretation during the analysis process. During the identification stage, 153 documents were retrieved.

Screening is done after the identification step. According to Zawacki-Richter et al. (2020), the documents selected for analysis must be assessed according to the criteria used in the study. Data was checked through the title, abstract, and keywords was carried out based on the required criteria.

Table 1
Analyzed documents

No	Authors	DOI Document
1	(Shah & Foster, 2014)	10.4018/ijvple.2014040101
2	(Foster & Shah, 2015)	10.2190/EC.51.4.a
3	(Foster & Shah, 2016)	10.4018/IJGCMS.2016070103
4	(Pérez et al., 2018)	10.7821/naer.2018.1.248
5	(Kaimara & Deliyannis, 2019)	10.1007/978-3-030-01551-0_6
6	(J. Li et al., 2019)	10.1145/3311350.3347174
7	(Papadakis et al., 2020)	10.5220/0009379902900298
8	(Flynn et al., 2021)	10.1016/j.ijcci.2021.100325
9	(Breien & Wasson, 2022)	10.3389/feduc.2021.775746
10	(Obery et al., 2023)	-
11	(Ishak et al., 2023)	10.3390/educsci13020102
12	(Villa et al., 2023)	10.3390/educsci13090964
13	(Saal et al., 2024)	10.1080/07380569.2024.2405518
14	(Stalheim & Somby, 2024)	10.1186/s40561-024-00308-7

Studies were included if they met the following criteria: (1) discussed Digital Game-Based Learning; (2) involved mathematics learning or mathematical concepts; (3) integrated cultural contexts into learning activities or game environments; and (4) contained empirical or conceptual discussions relevant to educational implementation. Studies were excluded if they: (1) focused solely on entertainment games without educational purposes; (2) discussed digital learning without game-based elements; (3) did not involve mathematics learning; or (4) did not contain identifiable cultural contexts.

During the screening stage, 118 documents were excluded for several reasons. A total of 42 documents were unrelated to mathematics learning, 31 studies discussed digital learning without game-based approaches, 33 studies lacked cultural contexts, and 12 studies were excluded because they lacked sufficient accessible information. After the screening process, 35 documents remained for full-text eligibility assessment.

After obtaining 35 documents, the next stage is eligibility. At this stage, an assessment is carried out using the help of The Joanna Briggs Institute (JBI) critical appraisal tools by making exceptions for documents that have a score below 50% (Aromataris et al., 2015). The assessment is carried out based on suitability with the matters to be observed, namely the type of research, research subjects, research instruments, mathematical materials, culture used as a learning context, measured variables, learning media used, research results, and research suggestions.

Each checklist item was scored using a binary assessment system, where "Yes" responses received one point and "No," "Unclear," or "Not Applicable" responses received zero points. The final score for each study was calculated as the percentage of fulfilled criteria relative to the total applicable criteria in the selected checklist. Studies obtaining scores below 50% were excluded because they were considered methodologically insufficient to support reliable synthesis. The quality assessment process was conducted independently by two researchers over a two-week period to reduce subjectivity and increase consistency in the evaluation process. To ensure inter-rater reliability, disagreements between reviewers were discussed collaboratively until consensus was achieved. When differences in interpretation could not be resolved directly, a third reviewer was consulted to provide additional judgment regarding the study eligibility or scoring results. A total of 14 documents were obtained, which had a value above 50%.

Document analysis conducted in this study is a document taken from the Scopus database (www.scopus.com) with details that can be seen in Table 1. The document analysis method used content analysis from Dan et al. (2024) and Khalid et al. (2025) which was modified for the sake of suitability of research objectives. Modifications were made by synthesis and replication between the two methods, namely by analyzing the year of publication, type of research, research subjects,

Table 2
Basic information

Data	Results
Publication Year	2014-2024
Total Documents Analyzed	14
Total Citations	508
Average Citations Per Year	44
Average Citations Per Document	36
Average Authors Per Document	3

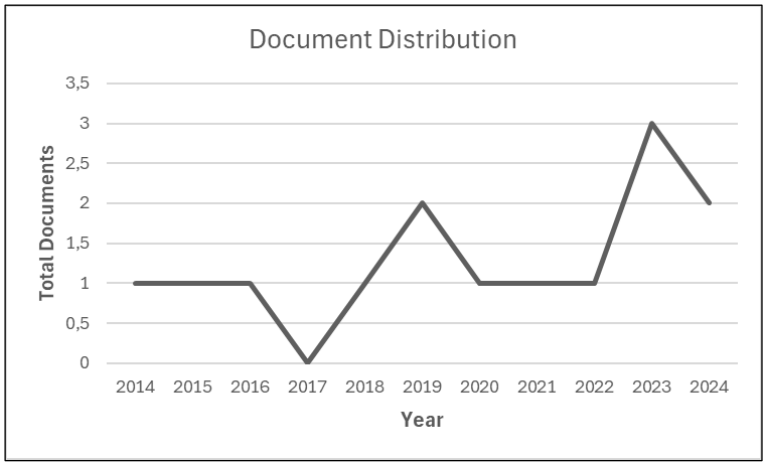

Figure 2. Publication of documents for 2014-2024

research instruments, mathematical material, culture used as a learning context, measured variables, learning media used, research results and research suggestions from the document.

The coding and categorization process was conducted manually using structured spreadsheet matrices because the number of eligible studies remained manageable for detailed interpretative analysis. The researchers systematically compared coding results, refined category boundaries, and synthesized thematic relationships across the reviewed studies to maintain analytical consistency. This approach allowed the review not only to describe bibliometric tendencies, but also to identify conceptual patterns and research gaps related to culturally contextualized DGBL in mathematics learning.

FINDINGS

The findings of this systematic literature review are presented according to the research questions formulated in the introduction. Rather than merely describing publication frequencies, this section synthesizes methodological tendencies, thematic patterns, forms of cultural integration, educational focuses, and emerging trends identified across the reviewed studies. A total of 14 studies met the inclusion criteria and were analyzed comprehensively.

General information of analyzed documents

Table 2 is the basic information of the documents analyzed as a whole. The reviewed studies were published between 2014 and 2024, indicating that research concerning Digital Game-Based Learning (DGBL) with cultural contexts in mathematics learning is still relatively limited and emerging. Although the number of publications remains small, the studies demonstrate growing scholarly interest in integrating mathematics learning, digital technology, and culturally responsive pedagogy. Most of the documents of the DGBL model with a cultural context in mathematics learning are written in groups, ranging from 2-5 authors with an average of 3 authors for the entire document. This can happen because a team is needed that includes educators, sometimes technology specialists, and game developers in designing games that will be implemented in the DGBL model (Breien & Wasson, 2022).

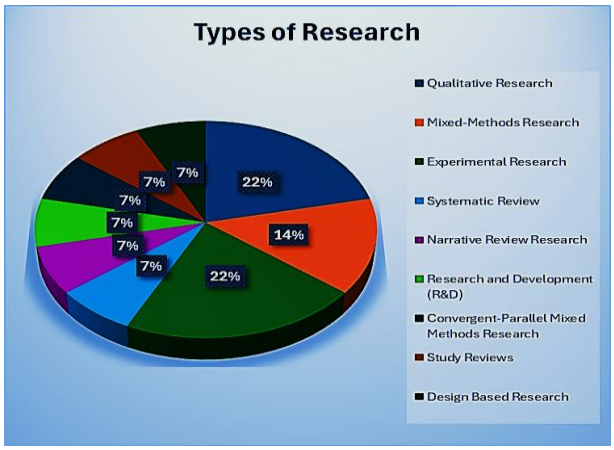

Figure 3. Analysis of research types in documents

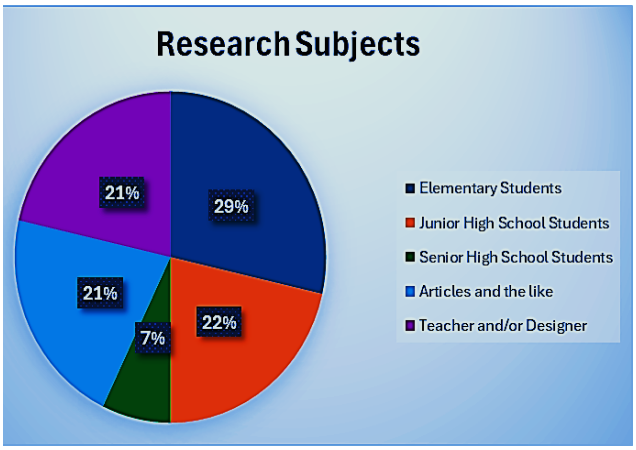

Figure 4. Analysis of research subjects in documents

The distribution of documents related to the DGBL model with a cultural context in mathematics learning can be seen in Figure 2. The publication trend also demonstrates that research activity increased gradually after 2018, with the highest number of publications appearing in 2023 and 2024. This increase may reflect broader educational interest in technology-enhanced learning environments following the rapid expansion of digital learning practices during and after the COVID-19 pandemic.

Research designs and methodological tendencies (RQ1)

Based on Figure 3, there are 9 types of research used in documents regarding the DGBL model with a cultural context in mathematics learning. The analysis revealed that qualitative research and experimental research were the most dominant methodological approaches used in studies related to DGBL with cultural contexts in mathematics learning. Qualitative studies commonly explored students' learning experiences. These studies emphasized interpretative understanding of how students interact with digital mathematics games and how cultural elements shape engagement and meaning-making processes. Whereas experimental research focused on evaluating the influence of DGBL in mathematics learning. Most intervention-based studies compared game-based learning environments with conventional instructional approaches to investigate differences in students' responses and learning outcomes.

Research subjects, educational levels, and instruments (RQ2)

There are five subjects studied in the research on the DGBL model with a cultural context in mathematics learning as listed in Figure 4. The most widely studied research subjects are students, including senior high school, junior high school and elementary school levels. 8 documents use students as research subjects. Among the three levels, elementary school students are the most widely studied subjects, namely 4 documents, junior high school students with 3 documents and senior high school students with 1 document. This pattern suggests that researchers tend to position DGBL as an instructional strategy particularly suitable for younger learners because digital games are often considered effective in increasing engagement, curiosity, and participation during early stages of mathematical learning.

Several studies also involved teachers, instructional designers, or game developers as research participants. These studies emphasized collaborative processes in designing culturally relevant digital learning environments and highlighted the importance of pedagogical considerations in educational game development.

Figure 5 shows that interviews and questionnaires are the most widely used by researchers as research instruments. Interviews are used in design-based, qualitative, and mixed-methods research. Whereas Questionnaires are used in design-based, experimental, and convergent-parallel mixed methods research. Observations and tests were also widely used. Tests are usually used in mixed-methods and convergent-parallel mixed-methods research, while observations are usually used for

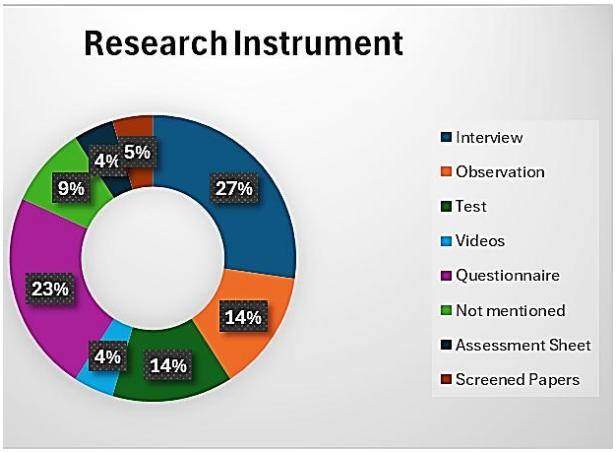

Figure 5. Analysis of research instruments in documents

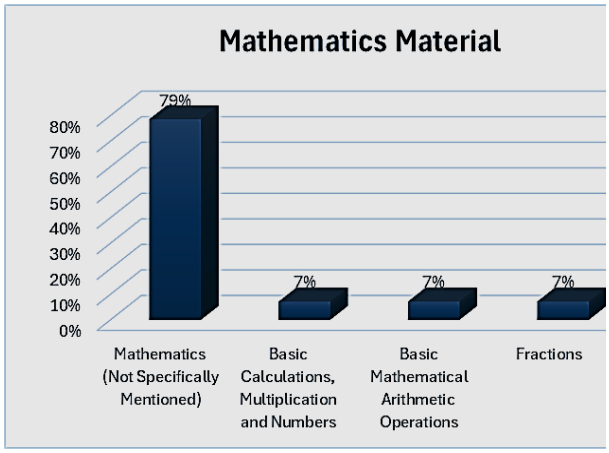

Figure 6. Analysis of mathematical material in documents

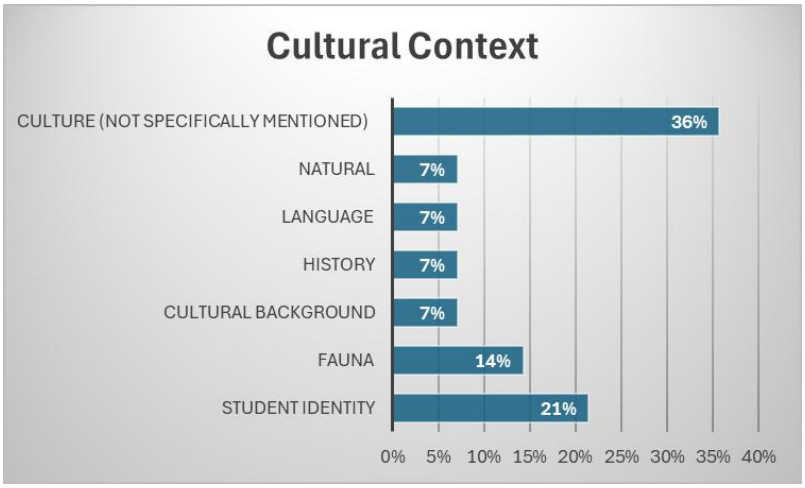

Figure 7. Analysis of cultural context in documents

qualitative and mixed-methods research. Assessment sheets are used in research and development (R&D) types and videos are used in mixed-methods research. Documents whose instruments use screened papers and those that do not mention the instrument are documented with the type of literature review research.

Mathematical materials and forms of cultural context (RQ3)

One important finding of this review concerns the limited specificity of mathematical content represented in many studies. Most reviewed documents discussed mathematics learning in general terms without clearly identifying the exact mathematical concepts taught through DGBL environments. Only three documents mention the material specifically, where the material used is basic calculations, multiplication and numbers (Pérez et al., 2018), basic mathematical arithmetic operations (J. Li et al., 2019) and fractions (Stalheim & Somby, 2024). The mathematical material used in the documents studied is shown in Figure 6.

The dominance of elementary-level mathematics topics suggests that culturally contextualized DGBL has been implemented primarily in foundational mathematics learning rather than advanced mathematical domains. More complex mathematical areas such as algebra, geometry, calculus, statistics, or mathematical modeling remain rarely explored in the reviewed studies. This limitation indicates that current DGBL research still focuses more heavily on engagement and introductory mathematical understanding than on higher-order mathematical reasoning.

Through Figure 7, it can be seen that the most widely used context in the study is the culture of 36% with 5 documents. Similarly, with mathematics materials, this can occur because the document doesn't specifically mention the culture in which it's used. It only mentions the cultural

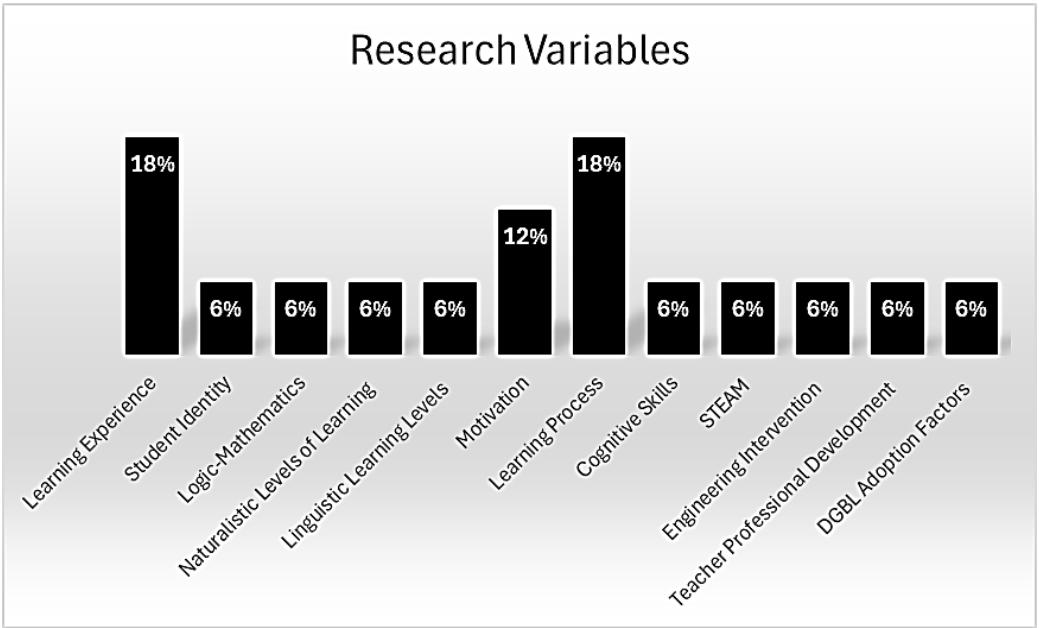

Figure 8. Analysis of research variables in documents

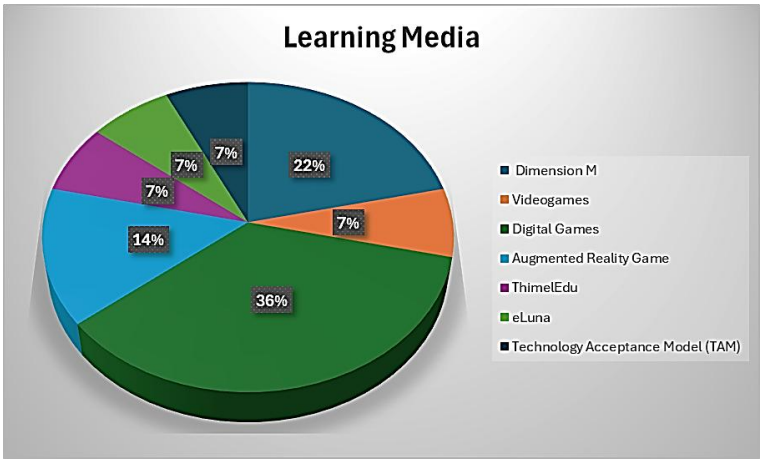

Figure 9. Analysis of learning media in documents

context in which it's used. A total of nine documents mention the context used specifically. There are six contexts identified from nine documents, namely student identity, fauna, cultural background, history, language and nature. The most widely used context among the identified contexts is student identity 21% with 3 documents. Through student identity, it allows students to draw a new avatar that they can connect and relate to their self-sense as it relates to their learning of mathematics and their identities (Foster & Shah, 2015; Shah & Foster, 2014).

In addition, some studies integrated local cultural practices, historical narratives, or indigenous knowledge systems into gameplay scenarios to contextualize mathematical concepts within familiar social experiences. Cultural integration was therefore not limited to decorative visual elements, but functioned as a mediating component connecting mathematical ideas with learners' lived realities. Environmental elements such as fauna or nature appeared in several studies; however, these elements were categorized as cultural contexts only when they were explicitly connected to local traditions, indigenous practices, community symbolism, or culturally meaningful narratives. Natural themes that functioned solely as aesthetic backgrounds without cultural significance were not interpreted as genuine cultural contexts within this review.

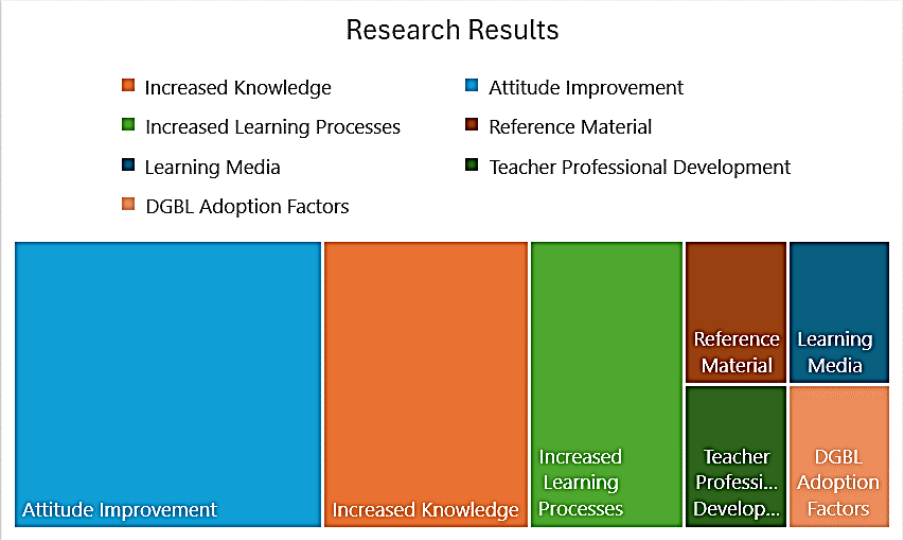

Figure 10. Analysis of research results in documents

Variables, learning media, and educational outcomes (RQ4)

There are twelve research variables in the document of the DGBL model with a cultural context in mathematics learning, where some documents use more than one research variable. The research variables used in the documents studied can be seen in Figure 8. The figure shows that researchers are more interested in researching the learning experience and learning process using the DGBL model with a cultural context in mathematics learning, amounting to 18% with 3 documents. This aims to see the impact of the DGBL model with a cultural context on mathematics learning and how students develop during learning (Ishak et al., 2023; Shah & Foster, 2014). Through a DGBL model with a cultural context in mathematics learning, it provides a significant learning experience and improvement in mathematics (Foster & Shah, 2015; Papadakis et al., 2020; Stalheim & Somby, 2024).

In Figure 9, it can be seen that the most widely used learning media in the study were digital games at 36% with 5 documents. In addition to digital games, Dimension M is also widely used in research, namely 22% with 3 documents. Dimension M is a profitable famous server-based first and third-person MMO educational game designed to engage students in mathematical practice (Foster & Shah, 2015). The game uses a 3D environment consisting of four mini-games: Tower Storm, Velocity, Meltdown, and Swarm (Shah & Foster, 2014).

Figure 10 shows the research results from the documents studied. Improvement in attitude is the most frequently obtained research result, which is 6 documents. This is in line with the findings regarding the research variables. Furthermore, the most frequently obtained results are increased knowledge, which is 4 documents, and increased learning processes, which is 3 documents. Based on the research results, the application of the DGBL model with a cultural context in mathematics learning has a positive effect.

Limitations and future research directions (RQ5)

The distribution of documents related to suggestions in the study is in Table 3. The table shows that the most suggestions refer to further research, namely 21 data with 16 suggestions. Even in one document, there can be more than one suggestion for further research. This can happen because of the many limitations in the study, so that through this suggestion in the future it can further explore the benefits of the DGBL model with a cultural context in mathematics learning. One major limitation concerns the relatively small number of studies available, indicating that this research area remains underdeveloped. Many studies also involved small participant groups, short intervention durations, and limited educational contexts, reducing the generalizability of findings.

In addition to those in the table, another recurring limitation relates to the insufficient specificity of mathematical materials and cultural frameworks. Numerous studies discussed cultural relevance broadly without providing detailed explanations regarding how cultural elements were

Table 3
Analysis of research suggestions

No	Objective	Suggestion	Total
1	Further Researcher	Examining games for transformative learning in gaming	2
		Improving reporting practices in game-based learning studies	1
		Using a larger sample	2
		Exploring variables over a longer duration	2
		Using a variety of learning contexts	1
		Proving the reasons DGBL is interesting and effectively used	1
		Provide direction on the implementation of games into the learning process	1
		Adapting to various situations in learning	1
		Taking into account the personal factors of students	1
		Using different techniques	2
		Using a different context	2
		Targeting STEAM	1
		Exploring cultural relevance	1
		Clarify political clarity	1
		Perfecting the media	1
		Using research as reference material	1
2	Government	Prioritize the development and implementation of aligned digital tools	1
		Conducting continuing professional development	1
		Conducting digital literacy training for teachers	1
3	Designer	Develop serious games	1
		Implementing tangible interactions in the game	1
		Taking advantage of diegetic feedback	1
		Emphasizing universal input	1
4	Teacher	Practice the ability to integrate GBL into the classroom	1
		Solving various problems that may arise in implementing GBL	1

systematically embedded into game mechanics, mathematical representations, or learning activities. Similarly, many studies focused predominantly on affective outcomes.

Next, most suggestions refer to designers, namely 4 data with 4 suggestions. The suggestion for designers is to develop serious games with tangible interactions and diegetic feeds and emphasize universal input more (Ishak et al., 2023; J. Li et al., 2019). The results of the research suggestion analysis also refer to the government, where there are 3 data with 3 suggestions. Policy recommendations that can be made to overcome obstacles in the implementation of DGBL models with a cultural context in mathematics learning are to prioritize the development and implementation of aligned digital tools and conduct ongoing professional development and digital literacy training for teachers to overcome technophobia (Saal et al., 2024). The results of the analysis suggest that teachers should train their ability to integrate GBL into the classroom and solve various problems that may arise in implementing GBL (Pérez et al., 2018).

Future research directions identified across the studies include the exploration of advanced mathematical topics, implementation in secondary and higher education settings, longitudinal investigations of learning impact, cross-cultural comparative studies, and stronger methodological designs involving larger participant samples. Researchers also emphasized the importance of examining how culturally contextualized DGBL can support inclusive mathematics learning environments in domains other than affective.

Overall, the findings demonstrate that culturally contextualized DGBL in mathematics learning has shown promising educational potential, particularly in strengthening students' engagement, motivation, and learning experiences. However, the field remains methodologically and conceptually fragmented, indicating the need for more rigorous, theoretically grounded, and pedagogically focused research in future investigations.

DISCUSSION

This systematic literature review demonstrates that research concerning Digital Game-Based Learning (DGBL) with cultural contexts in mathematics learning remains relatively limited despite increasing scholarly attention during the last decade. The gradual growth of publications after 2018 indicates that researchers have become increasingly interested in combining mathematics learning, digital technologies, and culturally responsive pedagogical approaches within a single instructional framework. The limited number of studies identified in this review suggests that the integration of cultural contexts into digital mathematics games is still an emerging area requiring further theoretical and methodological development. Designing culturally contextualized mathematics games involves not only technological considerations, but also pedagogical sensitivity, cultural understanding, and interdisciplinary collaboration among educators, instructional designers, and game developers (Breien & Wasson, 2022). Consequently, the complexity of integrating meaningful mathematical content with authentic cultural representation may explain why research in this field remains relatively fragmented and limited in scope.

The findings also indicate that qualitative and experimental research designs dominate the existing literature. This methodological tendency reflects two complementary research orientations within DGBL studies. Qualitative approaches are primarily used to explore students' learning experiences within culturally contextualized learning environments, while experimental studies focus on evaluating the influence of DGBL in mathematics learning. Through these two types of research, it is shown that researchers are trying to balance exploratory insights with empirical validation in studying the DGBL model with a cultural context in mathematics learning (Creswell & Creswell, 2018).

The dominance of elementary and junior high school students as research participants indicates that culturally contextualized DGBL is currently positioned primarily as an engagement-oriented instructional approach for younger learners. This could happen because digital games are a learning medium that can improve student motivation, attitudes, and performance (Byun & Joung, 2018). In addition, DGBL can stimulate great improvements in student productivity and creativity (Flores, 2015). However, the concentration of studies at foundational educational levels simultaneously reveals an important research gap. Advanced mathematics topics at secondary school education levels remain underrepresented in the literature, suggesting that researchers may still encounter difficulties in designing culturally meaningful game mechanics capable of supporting abstract mathematical reasoning.

The frequent use of interviews and questionnaires as research instruments reflects an emphasis on capturing subjective learning experiences and perceptions. This methodological preference corresponds with the affective domain of learning, where motivation, engagement, and attitudes are central constructs (Hui & Mahmud, 2023). Observation and test instruments complement this approach by providing triangulation data that strengthens the validity of findings in mixed-methods research.

One important issue emerging from this review concerns the limited specificity of mathematical content within many studies. Most reviewed documents discussed mathematics learning broadly without clearly identifying the mathematical concepts taught through DGBL environments. This phenomenon may be linked to the design complexity of integrating precise mathematics materials into engaging game mechanics while maintaining cultural authenticity (Plass et al., 2015). Only three documents mention the material specifically, where the material used is basic calculations, multiplication and numbers (Pérez et al., 2018), basic mathematical arithmetic operations (Li et al., 2019) and fractions (Stalheim & Somby, 2024). These three materials are materials for elementary school mathematics learning. This finding also indicates that the current development of culturally contextualized DGBL remains concentrated on introductory mathematical learning than deeper conceptual reasoning. So it can be concluded that mathematics materials in secondary schools need to be studied to explore the influence of using the DGBL model in various mathematics learning contexts (Chang & Hwang, 2019; Foster & Shah, 2016; Ishak et al., 2023).

Another important finding relates to the cultural context used in the research. The most widely used cultural context is the culture and identity of students. Cultural context integration, particularly

through student identity, highlights the role of sociocultural theory in learning. Learning is understood as a socially mediated process where knowledge construction is influenced by cultural tools and symbols. The use of identity-based avatars and culturally relevant narratives allows learners to connect mathematical concepts with their lived experiences, thereby enhancing engagement and meaning-making (Foster & Shah, 2015; Shah & Foster, 2014). In addition, by utilizing student identity, mathematics learning becomes relevant for students because students feel that mathematical problems are directly connected to their daily lives.

At the same time, this review identified considerable inconsistency in how culture was conceptualized and implemented across studies. Some documents provided detailed explanations of the cultural context in which they are used, whereas others referred to "cultural context" only in general terms without clarifying the cultural dimensions involved. This conceptual inconsistency indicates the absence of a standardized framework for integrating culture within DGBL mathematics learning. The findings therefore suggest that future research should establish clearer theoretical foundations regarding what constitutes meaningful cultural integration within educational game design.

In research variables, variables referred to are mostly affective, whereas the most widely used variables are learning experiences and learning processes. Students commonly described culturally contextualized game environments as more enjoyable, relatable, and meaningful (Ishak et al., 2023). Nevertheless, these findings should be interpreted carefully. The present review primarily synthesized thematic trends and variable occurrences rather than extracting statistical effect sizes or conducting meta-analytic calculations. Consequently, the findings do not provide conclusive evidence regarding the magnitude of DGBL effectiveness in improving mathematical achievement. So it can be concluded that the reviewed studies tend to support positive affective and experiential learning conditions.

The findings regarding learning media also demonstrate the increasing use of immersive digital environments, particularly three-dimensional (3D) educational games and interactive virtual platforms. The environment created is centered on the theme of the story (Nunes et al., 2022). Through digital games that use 3D environments, we can encourage positive impacts on learning and long-term knowledge retention that is appropriate to the level of the student's learning environment (Nunes, 2021).

The reviewed studies also highlight several methodological limitations that should be addressed in future investigations, such as conducting direct observations, extending the duration of the research, enlarging the research sample, exploring cultural relevance in DGBL, and designing and using DGBL models with a cultural context in mathematics learning (Foster & Shah, 2015, 2016; Papadakis et al., 2020; Pérez et al., 2018; Shah & Foster, 2014; Stalheim & Somby, 2024; Villa et al., 2023). In addition, comparative cross-cultural investigations and research involving advanced mathematical topics are still needed to provide a more comprehensive understanding of how culturally contextualized DGBL influences mathematics learning over time.

Overall, this review indicates that culturally contextualized DGBL possesses meaningful educational potential, particularly in strengthening engagement, relevance, and students' emotional connection to mathematics learning. However, the field remains theoretically fragmented and methodologically underdeveloped in several areas. Future research should therefore focus on developing clearer conceptual frameworks, stronger methodological designs, and deeper investigations into how cultural integration can support not only affective engagement, but also against other domains.

CONCLUSIONS

This systematic literature review examined the development of Digital Game-Based Learning (DGBL) with cultural contexts in mathematics learning by synthesizing findings from 14 selected studies published between 2014 and 2024. The review demonstrates that research in this field remains relatively limited and conceptually fragmented, despite growing international interest in integrating digital technologies, culturally responsive pedagogy, and mathematics learning. Existing

studies predominantly employ qualitative and experimental research designs and focus mainly on elementary and junior high school students. Interviews, questionnaires, observations, and tests are the most frequently used research instruments. Limitations identified across studies, including the lack of a specific focus on mathematics materials and cultural contexts and the limited scope of the research, point to the need for more targeted and diverse investigations. Documents that specifically mention the material are elementary school mathematics learning materials, while the most widely used cultural context besides culture is the identity of students.

In research results, variables referred to are mostly affective, whereas the most widely used variables are learning experiences and learning processes. Nevertheless, these findings should be interpreted carefully. The present review primarily synthesized thematic trends and variable occurrences rather than extracting statistical effect sizes or conducting meta-analytic calculations. Consequently, the findings do not provide conclusive evidence regarding the magnitude of DGBL effectiveness in improving mathematical achievement. The review also identifies several important limitations within the existing body of literature. Many studies involve small participant groups, short intervention durations, and context-specific implementations, limiting the generalizability of findings across broader educational settings. In addition, methodological inconsistencies and variations in defining cultural context indicate the need for clearer conceptual and theoretical frameworks within future DGBL research.

Based on these findings, future research should prioritize the development of theoretically grounded and pedagogically meaningful DGBL environments that integrate authentic cultural experiences with advanced mathematical learning objectives. Researchers are encouraged to explore secondary and higher education contexts, involve larger and more diverse participant populations, conduct longitudinal investigations, and employ stronger mixed-methods or experimental research designs. Future educational game development should also move beyond superficial cultural representation by embedding cultural narratives, practices, and identities directly into mathematical problem-solving activities and gameplay structures.

ACKNOWLEDGMENT

The authors would like to thank The International Seminar on Applied Mathematics and Mathematics Education (ISAMME) (IKIP Siliwangi) for the opportunity to provide space to present this research and provide useful suggestions for our research.

AUTHOR'S DECLARATIONS

Authors' contributions	ZZU: the study conception, research design, data collection, data analysis, interpretation of findings, and drafting of the manuscript. NP: the study conception, research design, manuscript drafting, manuscript revision, and final approval of the version to be published. DJ: the study conception, data analysis, interpretation of findings, manuscript revision, and final approval of the version to be published. TF: data collection, data analysis, and interpretation of findings.
Funding Statement	This research received no external funding and was financially supported by the authors.
Availability of data and materials	All data generated or analyzed during this study are available from the corresponding author upon reasonable request.
Competing interests	The authors declare that there are no conflicts of interest regarding the publication of this paper.

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