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Systematic Literature Review: Inquiry-Based Approaches and Educational Games in Elementary School Mathematics Learning

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Abstract

Although inquiry-based learning and educational game–based instruction have received increasing attention in prior studies, research specifically examining how both approaches can be systematically integrated to enhance conceptual understanding in elementary mathematics remains limited. This study aims to synthesize empirical evidence on the pedagogical alignment, effectiveness, and implementation challenges of combining guided inquiry and educational games in primary mathematics education. A qualitative systematic literature review (SLR) was conducted using the PRISMA framework, yielding a set of eligible articles selected through predefined inclusion criteria. Data were collected through structured document analysis and examined using thematic analysis to identify recurring patterns and relationships across studies. The findings indicate that guided inquiry and educational games exhibit strong pedagogical compatibility, with game features such as real-time feedback, adaptive challenges, and exploratory simulations reinforcing core inquiry processes. Integrated models were found to improve conceptual understanding, motivation, critical thinking, and problem-solving skills, while key challenges relate to teacher readiness, classroom management constraints, and limited technological access. Theoretically, these results contribute to the development

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of constructivist and inquiry-based learning frameworks and deepen understanding of how digital tools can support conceptual mathematics learning in early education. The study concludes that integrating guided inquiry with educational games offers a powerful and engaging learning environment for young learners and recommends that educators, curriculum designers, and policymakers adopt evidence-based integration strategies and invest in teacher training and digital infrastructure. The implications of this research include strengthened theoretical foundations for game-supported inquiry learning and practical recommendations for improving elementary mathematics instruction, while also highlighting opportunities for future research on model validation, long-term learning impacts, and culturally responsive game design.

Keywords: Guided Inquiry; Educational Games; Elementary Mathematics; Conceptual Understanding; Systematic Literature Review

INTRODUCTION

Mathematics is a fundamental discipline that plays a crucial role in developing logical, analytical, critical, and systematic thinking skills from the early years of schooling. At the elementary level, the goals of mathematics education extend beyond procedural fluency and basic computation skills; they also emphasize conceptual understanding as the foundation for meaningful learning. Conceptual understanding enables students to connect ideas, represent information in various forms, and apply their knowledge to solve both mathematical and real-world problems. As Ningrum et al. (2022) highlight, conceptual mastery is essential for problem solving because it allows students to construct new knowledge from prior experiences. Similarly, Anggraini (2023) argues that mathematics instruction in elementary schools must be contextual, exploratory, and meaningful, ensuring that learners not only memorize procedures but also grasp the underlying ideas.

Despite its importance, many studies report that elementary students' conceptual understanding of mathematics remains insufficient. Unaenah and Sumantri (2019) found that while students may complete tasks mechanically, many struggle to articulate the reasoning behind their solutions. The predominance of teacher-centered instruction contributes to this issue, leaving students with limited opportunities to actively construct mathematical ideas (Suciyati Sartika et al., 2022). Moreover, variations in students' cognitive styles and characteristics further challenge the effectiveness of conventional instructional approaches (Suranata et al., 2019). Drawing on the constructivist views of Piaget (1972) and

Vygotsky (1978), learning is not a passive transfer of knowledge but an active process shaped through interaction, scaffolding, and engagement with meaningful tasks (Murphy et al., 2025). In this context, guided inquiry emerges as a relevant learning approach. Through structured phases problem orientation, hypothesis formulation, exploration, conclusion, and reflection students actively construct their understanding based on evidence and experience. Studies by Suardana et al. (2019), Cahaya (2020), and Sudria et al. (2018) demonstrate that guided inquiry effectively enhances critical thinking and provides richer learning experiences. Additional research by Margunayasa et al. (2019), Yasin et al. (2019), and Kartono and Shora (2020) further supports its role in strengthening cognitive alignment, reflective thinking, and metacognitive reasoning.

Alongside pedagogical developments, technological innovation has introduced digital educational games as promising tools in mathematics learning. Mayer (2019) explains that games offer challenge-based environments with immediate feedback, facilitating exploration and concept reinforcement. Debrenti (2024) reports that digital games improve conceptual understanding and long-term retention through contextual simulations. Budasi et al. (2020) found that games significantly enhance motivation and academic achievement due to their interactive nature. Puzzle-based games have also been shown to foster creativity and problem posing (Candiasa et al., 2018), while Suartama et al. (2024) highlight their ability to promote collaboration and engagement. Barana et al. (2021) emphasize that real-time feedback in games helps students quickly identify and correct misconceptions, strengthening conceptual clarity.

Although guided inquiry and educational games have each demonstrated effectiveness, previous studies have largely examined them in isolation. Only a limited number of investigations have explored how these two innovations can be integrated to support mathematics learning in elementary schools. Yet, their combination holds substantial potential: guided inquiry provides the scientific reasoning framework, while educational games contribute motivational, interactive, and context-rich learning experiences. The scarcity of studies that address the integration of these approaches reveals a significant research gap, indicating the need for a systematic review that maps existing findings, identifies gaps in the literature, and offers insight for developing more comprehensive and evidence-based instructional strategies.

Furthermore, the practical implementation of guided inquiry in elementary schools remains challenging. Kastaun et al. (2021) argue that the cognitive demands of inquiry processes may overwhelm students, particularly those with lower initial abilities. Teachers often encounter difficulties in facilitating phases such as hypothesis formulation or conclusion drawing (Diani et al., 2024), resulting in inquiry lessons that become procedural rather than conceptually enriching. Digital educational games may help alleviate these challenges by providing structured visual support, engaging contexts, and guided exploration that complement the inquiry process. Studies by Asfar (2020) and Sabirli and Coklar (2020) suggest that integrating guided inquiry with digital games enhances intrinsic motivation, emotional engagement, and learning outcomes.

Given these considerations, the present study aims to conduct a Systematic Literature Review (SLR) on the integration of guided inquiry and educational games in elementary mathematics learning. Theoretically, this review seeks to strengthen the conceptual foundation supporting the integration of both approaches through constructivist and motivational learning perspectives. Practically, the findings are expected to provide evidence-based recommendations for teachers, instructional designers, and policymakers in creating learning environments that foster curiosity, active participation, and the effective use of digital technologies to enhance students' conceptual understanding of mathematics.

METHODS

This study employed a Systematic Literature Review (SLR) with a qualitative descriptive approach to comprehensively examine scientific publications discussing the application of guided inquiry and educational game media in mathematics learning at the elementary school level, particularly those related to the development of students' conceptual understanding. The use of the SLR method was based on its ability to provide a systematic, transparent, and structured evidence base that enables researchers to map existing findings, identify research gaps, and formulate directions for developing integrated instructional strategies (Snyder, 2019).

The SLR procedure in this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which are widely used in education and instructional technology research (Suryawan et al., 2023; Supratman et al.,

2025; Turmuzi & Suparta, 2023). The review process was conducted through four interrelated stages. The first stage, identification, involved searching for scientific articles across several online databases such as Google Scholar, ERIC, and Scopus. Searches were conducted using combinations of English and Indonesian keywords, including "inquiry-based learning," "game," "mathematics education," "guided inquiry," and "educational math games." The search was limited to scientific publications published from 2015 to 2025.

The second stage was screening, where all articles obtained from the initial search were filtered to remove duplicates and assess topic relevance based on titles and abstracts. Articles unrelated to mathematics learning, those not employing guided inquiry, or those not involving educational game media were excluded at this stage. The third stage, eligibility, required full-text examination of articles that passed the initial screening. Evaluation was conducted using predetermined inclusion and exclusion criteria, which considered topic relevance, educational level, completeness of research data, and conceptual contribution to the integration of guided inquiry and educational game approaches. These criteria are summarized in the following table:

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Articles discuss guided inquiry (guided inquiry, inquiry-based learning) and/or the use of educational game media (game-based learning, digital game learning, gamification) in mathematics learning.	Articles do not discuss guided inquiry or educational game media in the context of mathematics learning.
Articles published in accredited scientific journals (national journals indexed in SINTA 1–4, international journals, or Scopus-indexed) and peer-reviewed.	Articles originating from theses, dissertations, undergraduate papers, proceedings, or non-scientific sources.
Focus on elementary school level or equivalent.	Studies conducted at junior high school, senior high school, or higher education levels.
Article available in full-text format.	Article available only as abstract or preview.
Published between 2015–2025.	Published before 2015.

The final stage, inclusion, resulted in a set of articles that met all criteria and were deemed suitable for further analysis. The number of articles at each selection stage is

presented in a PRISMA flow diagram (Figure 1), which systematically and transparently illustrates the selection process from identification to final inclusion.

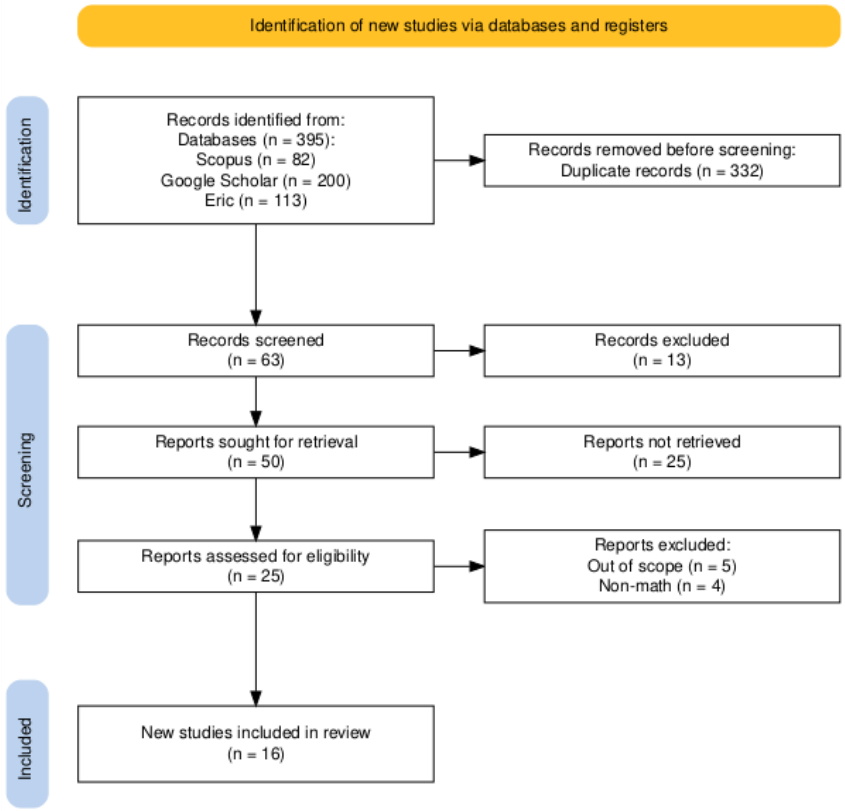


Figure 1. Workflow of the Literature Review Study

The included articles were analyzed using thematic analysis to identify patterns and relationships between guided inquiry and educational game media in elementary mathematics learning. The analysis focused on four main aspects: (1) Pedagogical Alignment and Integration Potential, (2) Game Features Supporting Inquiry Processes, (3) Impact on Conceptual Understanding and Learning Motivation, and (4) Implementation Challenges and Opportunities in Elementary Schools. The results are presented in a synopsis table and elaborated through descriptive narrative to clarify the connections between the reviewed studies and the four identified themes.

RESULTS

The results of this systematic review summarize the main findings from the selected studies regarding the integration of guided inquiry and educational game-based learning in elementary school mathematics instruction. The synthesis focuses on four core dimensions:

(1) pedagogical alignment and integration potential, (2) game features that support inquiry processes, (3) the impact on conceptual understanding and learning motivation, and (4) challenges and opportunities for implementation in elementary contexts. These findings collectively highlight patterns, thematic structures, and recurring characteristics across the reviewed literature.

Overall, the analyzed studies indicate that guided inquiry and educational games share strong pedagogical compatibility. Both emphasize exploration, active engagement, conceptual discovery, and meaningful learning through experience. Additionally, several game features such as real-time feedback, visual simulations, adaptive challenges, and interactive problem-solving tasks were found to align closely with the stages of inquiry, supporting students' ability to analyze problems, test ideas, draw conclusions, and reflect on their learning. The integration of these approaches has also been associated with notable improvements in students' conceptual understanding, intrinsic motivation, critical thinking, metacognitive skills, and persistence in mathematical problem-solving tasks.

To provide a clear overview of the findings, Table 2 presents a structured summary of the thematic results across the included studies. The table outlines the four central themes, the core insights generated from the literature, and the studies that contributed to each thematic category.

Table 2. Summary of Systematic Review Findings on Guided Inquiry and Educational Games in Elementary Mathematics Learning

Theme	Summary of Key Findings	Supporting Articles
1. Pedagogical Alignment & Integration Potential	Guided inquiry and educational games demonstrate strong compatibility because both emphasize exploration, conceptual discovery, and experiential learning. Games enable manipulation, simulation, and problem posing that reinforce inquiry processes. Non-digital inquiry tools (e.g., concrete manipulatives, puzzles) also provide foundational support for digital game-based inquiry.	Achmad (2018), Albano et al. (2021), Bang et al. (2023), Flaten (2025), Freitas et al. (2025), Hastuti et al. (2020), Karlina et al. (2020), Kirom & Aini (2023), Kurniasih et al. (2020), Lee et al. (2021), Liu (2023), MR et al. (2024), Sarifah et al. (2025), Sarifah et al. (2022), Sefnita Eka et al. (2018), Sukajaya et al. (2021)

Theme	Summary of Key Findings	Supporting Articles
2. Game Features Supporting Inquiry Processes	Effective game features include automatic feedback, manipulative exploration, leveled progression, adaptive challenges, collaborative missions, visual simulations, and AI-supported feedback. These features correspond to inquiry stages such as problem formulation, data gathering, hypothesis testing, and reflection.	Achmad (2018), Albano et al. (2021), Bang et al. (2023), Freitas et al. (2025), Kirom & Aini (2023), Kurniasih et al. (2020), Lee et al. (2021), Liu (2023), MR et al. (2024), Sarifah et al. (2025), Sarifah et al. (2022), Sukajaya et al. (2021)
3. Impact on Understanding & Learning Motivation	Most studies report significant improvements in conceptual understanding (e.g., number operations, geometry, KPK–FPB), intrinsic motivation, critical thinking, reasoning, metacognition, and problem-solving skills. Inquiry-based games increase students' engagement, persistence, and active participation.	Achmad (2018), Albano et al. (2021), Bang et al. (2023), Flaten (2025), Freitas et al. (2025), Hastuti et al. (2020), Karlina et al. (2020), Kirom & Aini (2023), Kurniasih et al. (2020), Lee et al. (2021), Liu (2023), MR et al. (2024), Sarifah et al. (2025), Sarifah et al. (2022), Sefnita Eka et al. (2018), Sukajaya et al. (2021)
4. Challenges & Opportunities in Implementation	Challenges include device availability, teacher readiness, child-friendly game design, and balancing game elements with instructional depth. Opportunities include increased conceptual accessibility, differentiated learning pathways, improved motivation, and alignment with competency-based curricula.	Achmad (2018), Albano et al. (2021), Bang et al. (2023), Flaten (2025), Freitas et al. (2025), Kirom & Aini (2023), Kurniasih et al. (2020), Lee et al. (2021), Liu (2023), MR et al. (2024), Sarifah et al. (2025), Sarifah et al. (2022), Sukajaya et al. (2021)

Following the synthesis in Table 2, the results indicate strong pedagogical compatibility between guided inquiry and educational game-based learning. Both approaches promote active participation, exploration, and conceptual construction, which align with the developmental characteristics of elementary students. Students tend to learn effectively when they are encouraged to investigate problems, make predictions, test ideas, and reflect on outcomes. When games are incorporated into this process, inquiry becomes more interactive and engaging, allowing students to understand mathematical concepts through meaningful experiences rather than memorization.

The analysis further shows that educational games used within an inquiry framework commonly incorporate features that support cognitive processing and self-regulated learning. Elements such as dynamic challenges, visual simulations, adjustable difficulty levels, and instant feedback help students navigate inquiry tasks more independently. These features guide learners through trial-and-error exploration, encourage

deeper reflection on mathematical processes, and create a structured yet flexible environment for developing problem-solving abilities.

The findings also highlight considerable gains in conceptual understanding and student motivation. Students become more persistent in completing learning tasks and more willing to explore complex mathematical ideas when engaged in inquiry-based gameplay. The interactive nature of game environments encourages learners to visualize abstract concepts, manipulate objects, and repeatedly test solutions until understanding is achieved. Across studies, improvements were consistently noted in areas such as reasoning, critical thinking, and the ability to connect mathematical ideas.

In addition to benefits, the reviewed literature points to several challenges in implementing inquiry-based game learning. Many schools face technical constraints, such as limited devices or inadequate digital literacy among teachers. Designing game interfaces that are developmentally appropriate for young learners also remains a challenge. Despite these barriers, opportunities for improvement are substantial. Schools can leverage inquiry-based games to support differentiated learning, strengthen conceptual clarity, and promote active involvement in mathematics. With proper teacher training, curriculum alignment, and resource allocation, the integration of guided inquiry and educational games holds strong potential for transforming mathematics learning in elementary education.

DISCUSSION

The findings of this systematic literature review reveal a strong convergence across studies indicating that the integration of guided inquiry and educational games offers substantial pedagogical advantages for elementary mathematics learning. These advantages are grounded in the complementary nature of both approaches, where guided inquiry provides the cognitive structure for scientific reasoning, while game-based learning offers motivational and experiential support. Achmad (2018) and Hastuti et al. (2020) emphasize that inquiry learning encourages learners to question, explore, and build understanding based on evidence processes that are naturally reinforced through interactive game environments. Educational games, especially those incorporating manipulatives, simulations, and adaptive challenges, create spaces where inquiry actions occur authentically, enabling students to experiment, validate hypotheses, and reflect on their

learning outcomes. This alignment confirms that guided inquiry and game-based learning share strong theoretical compatibility rooted in constructivism and experiential learning.

One of the most critical insights emerging from the reviewed studies is the significant role that digital game features play in supporting inquiry processes. Studies by Albano et al. (2021), Liu (2023), and Sukajaya et al. (2021) demonstrate that features such as automatic feedback, scaffolded levels, mission-based tasks, and manipulable virtual objects support each stage of the inquiry cycle: identifying problems, exploring data, testing assumptions, and reflecting on findings. Lee et al. (2021) further show that AI-driven feedback makes inquiry-based learning more personalized, enabling learners with varying cognitive styles to progress at their own pace. By providing instantaneous responses to student actions, games reduce ambiguity in the inquiry process and strengthen metacognitive awareness something that traditional instruction often struggles to achieve. This reinforces the argument that game-based learning does not merely supplement inquiry, but fundamentally amplifies its cognitive mechanisms.

In terms of learning outcomes, the integration of guided inquiry and educational games consistently yields improvements in conceptual understanding, problem-solving skills, and student motivation. Freitas et al. (2025) and Flaten (2025) highlight how visual and interactive simulations make abstract mathematical concepts more concrete, enabling students to internalize complex ideas such as geometry, number operations, and relational reasoning. Meanwhile, Albano et al. (2021) and MR et al. (2024) report that game-based inquiry fosters intrinsic motivation by combining cognitive challenge with emotional engagement. Students become more persistent, more curious, and more willing to engage in mathematical reasoning because the learning tasks feel purposeful and enjoyable. This aligns with findings by Sarifah et al. (2025), who note that inquiry-game integration creates a learning environment characterized by high engagement, sustained attention, and meaningful exploration.

However, despite these benefits, several challenges emerge in the practical implementation of this integrated approach. Studies by Karlina et al. (2020) and Sarifah et al. (2022) show that many teachers struggle to adopt guided inquiry due to limited training, insufficient confidence in facilitating open-ended exploration, and constraints of classroom time. These challenges become more pronounced when digital games are introduced, as teachers must also manage technical issues, align game content with curriculum standards,

and ensure that gameplay remains academically focused. Achmad (2018) and Bang et al. (2023) likewise note that inadequate infrastructure such as limited device availability or unstable internet access can hinder consistent implementation in schools. Despite these barriers, the literature indicates substantial opportunities for development. Educational games that are aligned with national curricula, equipped with teacher dashboards, and designed with child-friendly interfaces as proposed by Albano et al. (2021) and Freitas et al. (2025) can mitigate many implementation constraints.

From a pedagogical perspective, the integrated approach strengthens several crucial 21st-century competencies. Studies by Kirom & Aini (2023) and Sefnita Eka et al. (2018) show that inquiry-game environments develop reasoning skills, creativity, collaborative problem solving, and metacognitive awareness. These competencies are not merely supplemental but foundational for meaningful mathematics learning. Through repeated inquiry cycles embedded in playful contexts, students gain experience analyzing problems, comparing strategies, justifying reasoning, and revising solutions based on feedback. This iterative process mirrors scientific thinking and aligns with curriculum expectations that emphasize higher-order thinking and mathematical literacy.

The reviewed studies collectively indicate that guided inquiry and educational games are not two separate innovations but can be conceptualized as a unified model of interactive, reflective, and student-centered mathematical learning. Integrating both approaches addresses the cognitive limitations of unguided inquiry by providing structure and feedback, while simultaneously addressing the motivational limitations of traditional instruction by fostering curiosity, engagement, and enjoyment. As Freitas et al. (2025) conclude, the most effective learning environments are those that maintain a balance between challenge and support precisely the balance provided by inquiry-based games.

In summary, the literature strongly supports the integration of guided inquiry and educational games as a promising and theoretically grounded instructional model for elementary mathematics. Yet, it also highlights the need for strategic teacher training, improved digital infrastructure, and collaboration between curriculum designers and game developers. Future research should explore long-term learning effects, examine differential impacts on diverse student populations, and investigate how AI-enhanced games can further personalize inquiry learning. This review thus not only consolidates past findings

but also provides a roadmap for advancing innovative mathematics education aligned with the needs of 21st-century learners.

CONCLUSION

This systematic review demonstrates that the integration of guided inquiry and educational games holds strong pedagogical relevance and substantial potential for improving mathematics learning in elementary schools. Across the reviewed studies, both approaches consistently contributed to enhanced conceptual understanding, increased motivation, and deeper engagement in mathematical problem-solving. Guided inquiry provided a structured framework for scientific thinking, enabling students to explore, question, and construct meaning through evidence-based reasoning. Meanwhile, educational games enriched this process by offering interactive, visually supported, and feedback-driven environments that made abstract mathematical concepts more accessible and enjoyable. The combination of these two approaches fosters active learning, strengthens cognitive and metacognitive processes, and aligns well with the developmental characteristics of elementary learners.

Despite these promising outcomes, the findings also reveal practical challenges that must be addressed to ensure effective implementation. Limitations related to device availability, teacher readiness, alignment with curriculum standards, and the need for continuous scaffolding suggest that successful integration requires thoughtful instructional design and adequate professional development. Nevertheless, the opportunities for innovation are substantial. This review underscores the potential for guided inquiry and educational games to serve as complementary strategies that enhance both the quality and the relevance of mathematics learning. Future research is encouraged to explore long-term impacts, adaptive game design aligned with inquiry phases, and collaborative development between educators and technology designers to support more sustainable and scalable applications in elementary mathematics classrooms.

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