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ENHANCING METACOGNITIVE AND REFLECTIVE THINKING THROUGH WEB-BASED MATHEMATICS LEARNING MEDIA: A SYSTEMATIC LITERATURE REVIEW

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Abstract: The advancement of digital technology has encouraged the integration of web-based learning media to support higher-order thinking skills in mathematics education. However, studies examining how web-based mathematics learning media enhance both metacognitive and reflective thinking skills remain limited. This study aims to analyze research trends, technologies used, and the effectiveness of web-based mathematics learning media in improving students' metacognitive and reflective thinking skills. This study employed a Systematic Literature Review (SLR) using the PRISMA framework. A total of 33 articles published between 2020 and 2026 were selected from reputable international and national journals. The analysis was conducted based on four research questions: characteristics of web-based learning media, learning strategies used, support for metacognitive skills, and support for reflective thinking skills. The findings indicate that web-based mathematics learning media increasingly integrate technologies such as Artificial Intelligence, Augmented Reality, Virtual Reality, Learning Management Systems, and interactive multimedia. These technologies support metacognitive skills through planning, monitoring, and evaluation processes. Additionally, reflective thinking skills are enhanced through reacting, comparing, and contemplating activities in digital learning environments. This study concludes that web-based mathematics learning media effectively support higher-order thinking skills, particularly metacognitive and reflective thinking.

Keywords: mathematics learning media; metacognitive skills; reflective thinking; systematic literature review; web-based learning

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INTRODUCTION

In the 21st-century educational landscape, students are expected to possess a set of core competencies often conceptualized as the 4Cs: critical thinking, creativity, communication, and collaboration (Rabu & Badlishah, 2020). At the core of these skills lies problem-solving ability, which is a mandatory indicator in the acquisition of mathematical knowledge (S. D. Laksana, Setyosari, Praherdhiono, Kuswandi, & Jannan, 2024). As the foundation for various

other disciplines, mathematics is a required subject that must be studied at every level of education (Marthani & Ratu, 2022). Mathematics serves as a fundamental subject that develops logical, analytical, and systematic thinking (Sihombing et al., 2026). However, mathematics education globally, particularly in Indonesia, still faces significant challenges, as evidenced by low performance in international assessments such as the Programme for International Student Assessment (PISA) (Rahmaniah, Zainuddin, & Qadarsih, 2023). These low scores are often attributed to students' negative perceptions of mathematics as an abstract, difficult, and intimidating subject (Oktavia, Ardiawan, & Haryadi, 2024).

The root of this poor performance often lies in traditional teacher-centered instructional approaches that emphasize rote memorization over deep conceptual understanding, causing these methods to fail in fostering higher-order thinking skills, particularly metacognitive and reflective thinking (Mustika, Yanti, & Inayah, 2026). Metacognition, defined as awareness and control over one's own cognitive processes, is the key to educational success today (Sutarto, Muzaki, Hastuti, Fujiaturrahman, & Untu, 2022). It involves the stages of planning, monitoring, and evaluating learning strategies (Zeitlhofer, Hörmann, Mann, Hallinger, & Zumbach, 2023). Complementing this, reflective thinking is a rigorous learning process in which students analyze, examine, and validate information based on existing knowledge and experience (Rabu & Badlishah, 2020). These two skills are crucial for transforming students into independent, adaptive, and meaningful learners (Mustika et al., 2026).

Rapid advances in Information and Communication Technology (ICT) have brought about a paradigm shift from conventional classrooms to innovative virtual learning environments (Primasari, 2025). Web-based learning media, ranging from Learning Management Systems (LMS) and interactive modules to advanced technologies such as Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI), provide unique opportunities for higher-order thinking (Apiati (2024); Amalia, Haryadi, & Saefullah (2025); Su, Cheng, & Lai (2022); Saritepeci & Durak (2024)). Digital platforms facilitate interactivity, instant feedback, and the visualization of abstract concepts—all of which are crucial for fostering metacognitive awareness and reflective practice (Primasari, 2025). For example, the use of gamified interactive e-books, digital storytelling, and applications such as Nearpod has been shown to significantly improve students' ability to monitor and reflect on their learning journey (Chaisriya, (2023); Siswati et al. (2023); Zhao, Hwang, Chang, Yang, & Nokkaew (2021)).

Although research on digital technology in mathematics has advanced rapidly, much of the evidence remains fragmented, focusing on specific tools or isolated thinking skills (Primasari, 2025). The existing literature often presents inconsistent results depending on student characteristics or infrastructure limitations (Mustika et al., 2026). There is an urgent need for a comprehensive synthesis that maps how various web-based media specifically support the development of both metacognitive and reflective thinking in a mathematics context; furthermore, a structured review is essential to identify research trends, the most

effective technological architectures, and the pedagogical strategies employed in contemporary research.

Therefore, this study presents a Systematic Literature Review (SLR) following the PRISMA guidelines to examine the integration of website-based mathematics learning media. This review aims to answer four main research questions: (1) what are the current research trends regarding website-based mathematics learning media; (2) what specific technologies are used in their development; (3) how do digital learning media support students' metacognitive abilities; and (4) how do these media foster reflective thinking skills. By synthesizing empirical evidence from various digital learning environments, this article is expected to provide a strong foundation for educators and researchers to design more effective and adaptive learning strategies in the digital age.

METHOD

This study employed a Systematic Literature Review (SLR) method to analyze website-based mathematics learning materials in supporting students' metacognitive and reflective thinking skills. This method was chosen to systematically identify, evaluate, and synthesize research findings from various relevant studies (Sauer & Seuring, 2023). This study adopts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, which includes the stages of identification, screening, eligibility, and inclusion of articles. This study is designed based on the following four research questions:

What are the current research trends in web-based mathematics learning materials?
What technologies are used in the development of web-based mathematics learning materials?
How do digital learning materials support students' metacognitive skills?
How do digital learning materials support students' reflective thinking skills?

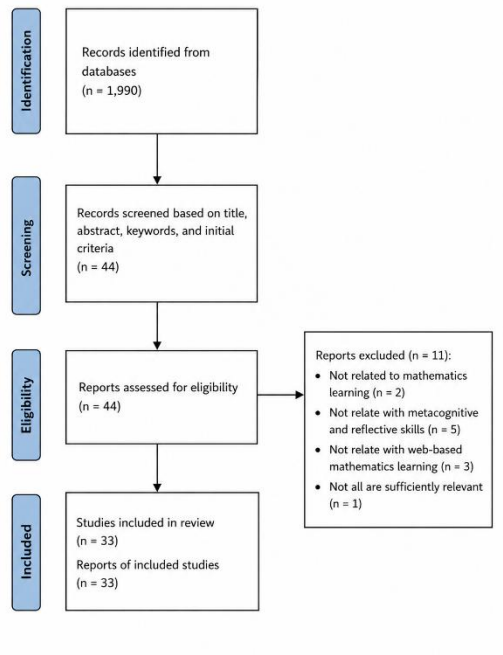

Figure 1. PRISMA Flowchart

The literature search was conducted using the Google Scholar and Scopus databases with keywords such as web-based mathematics learning, digital mathematics learning media, metacognitive skills in mathematics, and reflective thinking in mathematics. The collected articles were limited to publications from 2020 to 2026 to obtain the latest research relevant to developments in digital learning technology. The collected articles were sourced from journals indexed in Sinta 1–4 and Scopus Q1–Q3. The initial search yielded 1,990 articles. A screening process was then conducted based on titles, abstracts, and alignment with the research focus. Following this screening stage, 44 articles met the initial criteria. During the eligibility phase, a full-text analysis was conducted, resulting in the elimination of 11 articles due to their lack of alignment with the research focus. Ultimately, 33 articles met the inclusion criteria and were used in the Systematic Literature Review analysis. Data analysis was conducted using qualitative descriptive methods by grouping articles based on the characteristics of website-based learning media, the learning strategies used, and support for students' metacognitive and reflective thinking skills. The results of the analysis were then presented in the form of a synthesis table and a comprehensive discussion to answer the research questions.

RESULT AND DISCUSSION

Based on the analysis of the 33 selected articles, various findings were obtained regarding the use of website-based mathematics learning media in enhancing students' metacognitive and reflective abilities. The analysis was conducted systematically based on predetermined research questions to identify research trends, the technologies used, and the role of website-

based learning media in metacognitive and reflective abilities. The results of the synthesis of these articles are then presented in tabular form and discussed in detail under each of the following research questions.

Research Question 1: What are the research trends regarding website-based mathematics learning media?

Table 1. The Research Trends Regarding Website-Based Mathematics Learning Media

Author and Year	Research Method	Research Focus	Result
Ubaydullaeva et al. (2024)	Qualitative research and framework development	Development of Web-Based Smart E-Learning with Online and Offline Modes	The system enhances learning satisfaction and access to education
F. S. W. Laksana (2022)	Research and Development	Web-based math learning chatbot	A valid, practical, and effective learning tool
Fasa & Purwanti (2023)	Research and Development (ADDIE)	Geometry learning website	A highly valid and engaging learning tool
Aryani, Patmawati, & Santika (2023)	Quantitative Experiment	Web-based Nearpod in mathematics learning	Improving students' mathematical communication and motivation
Oktavia et al. (2024)	Research and Development	Flat-sided 3D shapes website	Improving students' mathematical communication

Based on Table 1, research on web-based mathematics learning media has seen significant growth from 2022 to 2024. Research trends indicate that web-based learning media are not only used as a means of delivering content but are also being developed to enhance various mathematical skills among students, such as mathematical communication, learning motivation, and conceptual understanding. Additionally, some studies have begun integrating more advanced technologies, such as chatbots, learning analytics, and web-based adaptive learning systems. Research by Ubaydullaeva et al. (2024) demonstrates that web-based learning media can overcome infrastructure limitations through online and offline learning systems. Meanwhile, research by F. S. W. Laksana & Fiangga (2022) developed a web-based chatbot capable of enhancing the interactivity of mathematics learning. Other studies, such as that by Oktavia et al. (2024), also demonstrate that website-based learning media can improve students' mathematical communication skills through the integration of various digital platforms. However, most research still focuses on improving basic cognitive skills such as conceptual understanding and mathematical communication. Research specifically aimed at developing website-based learning materials to support metacognitive skills and reflective thinking remains limited. Therefore, there is a need to develop website-based learning materials explicitly designed to support students' metacognitive learning and reflective thinking skills in mathematics education.

Research Question 2: What technologies are used in the development of website-based mathematics learning materials?

Table 2. Technology used in the development of web-based mathematics learning materials

Author and Year	Research Method	Research Focus	Result
Viberg et al. (2023)	Case study	Integration of the web-based MathAid application into mathematics education	Integration is not yet optimal because it is not aligned with the curriculum
Opesemowo & Ndlovu (2024)	Conceptual study	Integration of Artificial Intelligence into mathematics education	AI supports personalized learning but poses ethical risks
Su et al. (2022)	Experiment	Virtual Reality-based geometry education	VR enhances motivation and learning outcomes
Marthani & Ratu (2022)	Research and Development (ADDIE)	Development of digital media using Adobe Animate	The media is valid, practical, and effective
Sungkono et al. (2022)	Research and Development (ADDIE)	Development of AR-based GEO3DAR media	The media is suitable and enhances visualization
Irawan et al. (2023)	Research and Development (4D)	Interactive multimedia based on Scratch	The media is highly suitable and enhances computational thinking

Author and Year	Research Method	Research Focus	Result
Sihombing et al. (2026)	Research and Development	Educational games based on Canva	Media enhances learning motivation
Shoaib et al. (2024)	Research and Development (UCD)	Mathematics mobile apps for the visually impaired	Enhances user satisfaction
Darmayanti et al. (2022)	Research and Development (4D)	Digital comics based on Canva and Book Creator	Enhances students' critical thinking
Ulia et al. (2022)	Research and Development (Plomp)	Digital mathematics story media using iSpring	Enhances students' problem-solving skills

Based on Table 2, the technologies used in the development of website-based mathematics learning materials are highly diverse and continue to evolve in line with advancements in digital technology. Research indicates that the technologies employed are not limited to simple website platforms but also include the use of Artificial Intelligence, Virtual Reality, Augmented Reality, Scratch, Canva, and various other interactive multimedia tools. Research by Viberg et al. (2023) indicates that the use of web-based technologies such as MathAid can support mathematics learning; however, the integration of these technologies remains suboptimal due to a lack of alignment with the curriculum and teachers' instructional strategies. Additionally, Opesemowo & Ndlovu (2024) demonstrate that Artificial Intelligence technologies like ChatGPT and Photomath can support adaptive learning and provide instant feedback to students. Other studies also highlight the use of more innovative technologies, such as Virtual Reality by Su et al. (2022), which can enhance students' motivation and understanding of geometric concepts. Meanwhile, Sungkono et al. (2022) developed Augmented Reality-based media to aid in the visualization of abstract mathematical concepts. Furthermore, the use of Canva, Scratch, and iSpring also demonstrates that web-based interactive multimedia can increase student engagement in mathematics learning. Although various technologies have been utilized in the development of website-based mathematics learning media, research that integrates Artificial Intelligence–based technology, particularly to support metacognitive skills and reflective thinking

abilities, remains very limited. Therefore, the development of website-based learning media integrated with AI presents an important research opportunity to enhance the quality of mathematics learning based on digital technology.

Research Question 3: How do digital learning tools support students' metacognitive skills?

Table 3. Digital Learning Tools that Support the Development of Students' Metacognitive Skills

Author and Year	Research Method	Research Focus	Result
Heeyoon Ko (2026)	Quantitative PLS-SEM	Digital learning competence and metacognitive self-regulation	Metacognitive self-regulation enhances students' ability to plan, monitor, and evaluate the learning process
Ramlah, dkk. (2023)	Qualitative case study	Canva-based Digital Puzzle Worksheet	Enhancing students' metacognitive awareness in solving math problems
Sutarto, dkk. (2022)	Research and Development (4D)	Ethno-mathematics-based e-module	Enhancing students' planning, monitoring, and evaluating skills
Rahmaniah & Zainuddin (2023)	Research and Development (ADDIE)	Metacognitive-based digital module	Significantly enhancing students' metacognitive thinking skills
Chaisriya, Kaeophanuek, dan Gilbert (2023)	Quasi-experiment	Metacognitive-Based Digital Storytelling	Enhancing students' awareness of the thinking process
Bea Hana Siswati, dkk. (2023)	Quasi-Experiment	Nearpod Digital Learning	Enhancing students' metacognitive skills and self-regulation

Author and Year	Research Method	Research Focus	Result
Irfan Yusuf dan Sri Wahyu Widyaningsih (2020)	Lesson Study	E-Learning-Based Virtual Laboratory	Enhancing monitoring and evaluation of student learning, significantly improving students' metacognitive skills in each session
Fedriana Misa'adah dan Scolastika Mariani (2021)	True Experiment	Edmodo-based PjBL	Enhancing students' metacognitive awareness in problem-solving
Kübra Gül Çiftci dan Bahadır Yıldız (2024)	Action Research	Scratch-based digital game	Enhancing students' evaluation and control of their thinking
Jiahua Zhao, dkk. (2021)	Quasi-experimental	Gamified interactive e-book	Enhancing students' metacognitive tendenciesS

Based on Table 3, digital learning media play an important role in improving students' metacognitive abilities in mathematics learning. The metacognitive skills enhanced include the ability to plan, monitor, and evaluate students' thinking processes during learning activities. Digital media such as e-modules, digital storytelling, virtual laboratories, and gamified e-books enable students to be more active in independently controlling their learning processes. Research by Ko (2026) shows that metacognitive self-regulation plays a significant role in improving students' academic achievement through their ability to independently control their learning processes. In addition, Sutarto et al. (2022) developed an ethnomathematics-based e-module that was proven to significantly improve students' metacognitive abilities compared to conventional modules. This indicates that digital media can help students understand their thinking processes more systematically. Furthermore, research by Rahmaniah et al. (2023) revealed that metacognitive-based digital modules can

improve students' abilities to plan problem-solving strategies, monitor their working processes, and evaluate learning outcomes. Moreover, the use of the Nearpod platform by Siswati et al. (2023) and Scratch-based digital games by Çiftci & Yıldız (2024) also demonstrate that digital media can help students develop their metacognitive awareness through interactive activities. However, most studies still utilize general digital media such as e-modules, games, and digital learning platforms without integrating Artificial Intelligence–based technology. In addition, research specifically developing website-based mathematics learning media to support students' metacognitive abilities remains limited. Therefore, the development of website-based mathematics learning media integrated with Canva AI is important to support students' metacognitive abilities more optimally and innovatively.

Research Question 4: How do digital learning tools support students' reflective thinking skills?

Table 4. Digital Learning Tools that Support Students' Reflective Thinking Skills

Author and Year	Research Method	Research Focus	Result
Saritepeci & Durak (2024)	Quasi-Experimental	Integration of AI in Design-Based Learning	The integration of AI significantly enhances students' reflective thinking skills through activities such as evaluating ideas, revising designs, and reflecting on the learning process
Amalia et al. (2025)	Quasi-Experimental	AR Based on Visual Thinking Strategy	The ViTSAR medium enhances students' reflective abilities in the Reacting (52%), Comparing (29%), and Contemplating (33%) indicators
Apiati (2024)	Research and Development (Borg and Gall)	LMS-Based RME Module	Students' reflective thinking abilities increased significantly, with an average score of 80.15 compared to 46.15 in the control class
Emilya & Putri (2025)	Experimental	Game-based Kahoot	Students with a reflective learning style demonstrated high precision and a tendency

Author and Year	Research Method	Research Focus	Result
			toward deep reflection during learning
Mustika et al. (2026)	Pre-Experimental	Interactive video based on the flipped classroom	The media encourages reflective activities through the processes of planning, monitoring, and evaluating learning
Rahim et al. (2022)	Research and Development (ADDIE)	Lectora-based interactive media	The media helps students engage in reflection through concept visualization and assessment of understanding
Rabu & Badlishah (2020)	Qualitative Descriptive	Google Docs collaborative learning	Comment features encourage deep reflection and peer evaluation
Sari et al. (2025)	Quasi-Experimental	PBL-based animated video	Students reach the stage of critical reflection with the ability to evaluate and draw conclusions independently

Based on Table 4, digital learning media have been shown to play an important role in improving students' reflective thinking skills in learning. The development of reflective thinking skills includes the ability to evaluate thinking processes, compare strategies, and draw conclusions independently during the learning process. Digital media provide opportunities for students to engage in reflection through interactive activities, concept visualization, and immediate feedback. Research by Saritepeci & Durak (2024) shows that the integration of Artificial Intelligence in Design-Based Learning can improve students' reflective thinking skills through iterative design revision and idea evaluation processes. In addition, research by Amalia et al. (2025) indicates that the use of Augmented Reality based on Visual Thinking Strategy significantly improves students' reflective thinking indicators, namely reacting, comparing, and contemplating. Furthermore, Apiati (2024) found that a realistic mathematics module based on a Learning Management System significantly improved students' reflective thinking abilities compared to conventional learning. Moreover, the use of Google Docs as a collaborative medium Rabu & Badlishah (2020) also encourages students to engage in deeper reflection through peer interaction and evaluation. Other studies,

such as the use of flipped classroom–based interactive videos Mustika et al. (2026) and Problem-Based Learning–based animated videos Sari et al. (2025), also demonstrate that digital media can help students reach the stage of critical reflection, where students are able to evaluate solutions, develop new ideas, and draw conclusions independently. However, most studies still utilize general digital media such as interactive videos, LMS, and collaborative platforms without specifically integrating Artificial Intelligence technology into mathematics learning. In addition, research that develops website-based mathematics learning media to support students' reflective thinking skills remains limited. Therefore, the development of website-based mathematics learning media integrated with Canva AI is important to support students' reflective thinking skills more optimally and innovatively.

The analysis results indicate that web-based mathematics learning media have diverse characteristics and continue to evolve through the utilization of interactive digital technologies. These media are generally equipped with features such as interactive visualization, automatic feedback, self-assessment, and collaboration facilities that enable students to actively engage in the learning process. In addition, commonly implemented learning strategies include problem-based learning, flipped classroom, collaborative learning, the use of interactive videos, and the integration of artificial intelligence that supports adaptive and student-centered learning. These strategies provide opportunities for students to develop a deeper understanding of mathematical concepts while simultaneously enhancing higher-order thinking skills.

Furthermore, web-based learning media have been shown to enhance students' metacognitive abilities through planning, monitoring, and evaluating thinking processes. As stated by Nindiasari et al. (2026), website-based learning can improve reflective thinking skills through a metacognitive approach. Features such as self-reflection, immediate feedback, and interactive exercises help students regulate their learning independently. In addition, digital learning media support reflective thinking through problem analysis, strategy evaluation, and conclusion drawing based on learning experiences. Overall, web-based mathematics learning media have strong potential to integrate metacognitive and reflective skills, supporting more effective and interactive mathematics learning oriented toward higher-order thinking skills.

CONCLUSION

Based on the results of the systematic literature review, web-based mathematics learning media demonstrate significant potential in enhancing students' metacognitive and reflective thinking skills. The analyzed studies indicate that web-based learning media are generally designed with interactive features such as visualization, feedback, self-assessment, and collaborative tools that support active and student-centered learning. These features allow students to engage more deeply in learning activities and encourage them to regulate their own learning processes.

Furthermore, the implementation of various learning strategies, including problem-based learning, flipped classroom, collaborative learning, interactive video, and artificial intelligence integration, contributes to the development of higher-order thinking skills. These approaches provide opportunities for students to plan, monitor, and evaluate their learning, which are essential components of metacognitive skills. In addition, reflective thinking skills are developed through activities that encourage students to analyze problems, evaluate strategies, and draw conclusions from their learning experiences.

Overall, web-based mathematics learning media provide an effective learning environment that supports both metacognitive and reflective thinking skills simultaneously. Therefore, integrating web-based learning media in mathematics education can be considered a promising approach to improving students' higher-order thinking skills and fostering more meaningful learning experiences in the digital era..

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