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Systematic Literature Review: Digital Learning Media in Supporting Students' Mathematical Representation Skills

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Abstract

The growth of digital technology has opened up new opportunities to strengthen students' mathematical representation skills, particularly through learning media that are both interactive and contextual. With this in mind, the present study seeks to examine research trends, the types of digital learning media used, the educational levels involved, and the aspects of mathematical representation that have been explored. A PRISMA-based Systematic Literature Review was conducted by examining and synthesizing evidence from 33 relevant studies published between 2016 and 2025. The findings reveal a consistent upward trend in studies examining digital learning media. GeoGebra emerges as the most dominant tool, used in 36% of the reviewed research, followed closely by digital learning materials like e-modules and e-worksheets (24%) and audiovisual media (15%). Interestingly, junior high school appears to be the most common educational level studied, with most research giving particular attention to visual representation. Research is predominantly conducted at the junior high school level, with a primary focus on visual representation. Meanwhile, verbal representations have been relatively under-studied, indicating a research gap. These findings suggest that the development of digital learning media needs to be balanced to support all aspects of students' mathematical representation skills.

Keywords: Digital Learning Media, Mathematical Representation Skills, Mathematics Education, Systematic Literature Review.

1. Introduction

The abstract nature of mathematics often becomes an obstacle for students in understanding concepts. As a result, students experience difficulties in interpreting and connecting mathematical concepts with concrete situations. Mathematical representation ability is one of the key skills that contributes significantly to resolving these issues. Mathematical representation ability refers to students' capacity to express, organize, and communicate mathematical ideas through multiple forms, including visual, symbolic, and verbal representations. Diagrams, tables, graphs, and illustrations are examples of visual representations, whereas symbolic representations involve the use of mathematical symbols, notations, and equations. Meanwhile, verbal representation relates to the ability of students to explain mathematical ideas or problem-solving processes using spoken or written language. Students with well-developed representation skills are generally better able to communicate mathematical thinking and establish meaningful connections among mathematical concepts (Nangim & Hidayati, 2021). However, the development of these three components has not

reached an optimal level in practice, especially within Indonesia's educational setting, where conventional teaching approaches still prevail. Additionally, visual representation is more commonly examined since it is simpler to observe and assess, and its development is closely tied to how digital learning media are utilized.

This situation suggests that students' weak ability in mathematical representation in Indonesia continues to be an issue that needs serious attention. One of the contributing factors is the use of inappropriate learning media that has not been able to stimulate the visualization process optimally (Haryudita & Noer, 2024). This can create cognitive barriers in connecting data with graphical and symbolic representations. As a result, learning media capable of presenting mathematical concepts in a more dynamic and interactive way becomes essential. A number of studies point out that incorporating interactive digital media can help ease students' cognitive load and support their conceptual understanding, though how effective this turns out to be still hinges on the instructional design used (Fadila et al., 2025).

Digital learning media has come to represent a new paradigm, one that helps overcome the spatial and temporal limitations often found in traditional teaching. Dynamic software tools like GeoGebra, Wolfram Mathematica, and Autograph have been shown through empirical research to give students opportunities for exploratory learning (Haryudita & Noer, 2024). hese media make it possible to turn once-static concepts into dynamic visualizations — for example, in functions and geometry, where students can watch changes unfold in real time. In actual classroom settings, digital media are often paired with instructional models like Problem-Based Learning and Discovery Learning, both of which push students to take an active role in building their own knowledge. Through this integration, students gain the ability to explore concepts on their own terms and draw connections across different forms of mathematical representation. As technology keeps moving forward, digital learning media have grown more varied as well, no longer confined to math-specific software but now including creative platforms such as Canva, animated videos, and Android-based e-modules. Rather than serving solely as visualization tools, these media also function as learning environments that promote active and interactive engagement (Bito & Masaong, 2023)

However, despite the growing volume of research on digital media, fragmentation of findings regarding which media is most effective for particular subject matter or educational levels remains prevalent. Digital media is frequently employed merely as administrative support without meaningful pedagogical integration with respect to mathematical representation aspects. Challenges such as the technology access gap, teacher readiness, and the validity of independently developed digital content continue to be pressing issues in the current literature (Maulida et al., 2025). These conditions indicate the importance of conducting a comprehensive review to obtain a clearer understanding of the contribution of digital learning media to mathematical representation skills.

Despite this growing body of research, no systematic literature review has yet been conducted to explicitly compare these fragmented findings. To date, there is no SLR that compares the various types of digital learning media used across mathematics education studies, compares which aspects of mathematical representation ability (visual, symbolic, and

verbal) are most frequently targeted by these media, compares how the use and effectiveness of digital media differ across educational levels, from elementary to higher education, or systematically maps the research trends in this field over the past decade. Without such a synthesis, researchers and practitioners lack a clear, evidence-based picture of which types of media are best suited to particular representational aspects or educational contexts, and important patterns in how this research area has developed over time remain unidentified. This gap underscores the need for a systematic review that not only compiles existing findings but explicitly compares and maps them along these four dimensions.

This gap becomes clearer when situated against existing SLR studies in related areas. A. Hidayat & Chao (2025) conducted a systematic review of digital learning in Indonesian mathematics education, but their focus was directed toward teachers' knowledge, skills, and dispositions in adopting digital tools, rather than toward students' mathematical representation ability or a comparison across media types. Similarly, a recent SLR on the role of digital learning media in mathematics instruction under Indonesia's Merdeka Curriculum synthesized findings on media such as Canva, Wordwall, and educational games, but did not disaggregate its findings by educational level or by specific representational aspect (visual, symbolic, or verbal). On the other side, an SLR examining Indonesian students' mathematical representation ability approached the topic through the lens of self-efficacy and students' thinking styles, without addressing the role of digital media at all. None of these reviews, therefore, simultaneously compares media types, representational aspects, and educational levels, nor systematically maps research trends over time within a single synthesis. The present study addresses this combined gap by offering an integrated review that maps all four dimensions concurrently, thereby providing a more comprehensive evidence base than has been available from prior, narrower reviews.

Based on the aforementioned elaboration, a systematic study is needed to analyze the development of research related to the use of digital learning media in mathematics learning, particularly with regard to students' mathematical representation ability. Therefore, this study adopts a SLR approach to collect, evaluate, and synthesize research findings published between 2016 and 2025. This study aims to address several research questions, namely: (1) What are the research trends in the use of digital learning media in improving students' mathematical representation ability?, (2) What types of digital learning media are used to enhance students' mathematical representation ability?, (3) At which educational level is research on the use of digital learning media most frequently conducted?, and (4) Which aspects of mathematical representation ability are most dominantly examined in the research?. The findings of this review are expected to provide a comprehensive overview of the utilization of digital learning media in mathematics learning, as well as serve as a reference for the development of future research and learning practices.

2. Methods

This research relies on a Systematic Literature Review approach to gather, evaluate, and synthesize findings from earlier studies on the use of digital learning media in

mathematics education (Muslimah et al., 2025). The SLR method was chosen mainly because this topic has already received considerable attention in prior research, which made it possible to carry out a deeper synthesis of the available evidence. Through this review, the study seeks to present a comprehensive picture of what previous research has found regarding how digital learning media has been integrated into mathematics instruction and how it has contributed to the growth of students' mathematical representation skills.

The literature search process was conducted through the Google Scholar database within the timeframe of 2016–2025, using a combination of keywords: ("Media Pembelajaran Digital" OR "Media Digital" OR "Pembelajaran Berbasis Teknologi") AND ("Kemampuan Representasi Matematis" OR "Representasi Matematis") AND ("Pembelajaran Matematika"). The search keywords were strategically developed to maximize the retrieval of relevant studies and minimize the inclusion of literature outside the scope of this review.

Google Scholar was selected as the search database because this study focuses specifically on the Indonesian educational context, with search keywords constructed in Bahasa Indonesia. Google Scholar offers broader coverage of nationally accredited Indonesian-language journals than international databases such as Scopus or Web of Science, and it indexes content from multiple sources, achieving nearly comprehensive citation coverage of both databases (Martín-martín et al., 2021). This makes it a suitable single-source option for an SLR focused on a regional context, although reliance on a single database is acknowledged as a limitation, which is further addressed in the Discussion section.

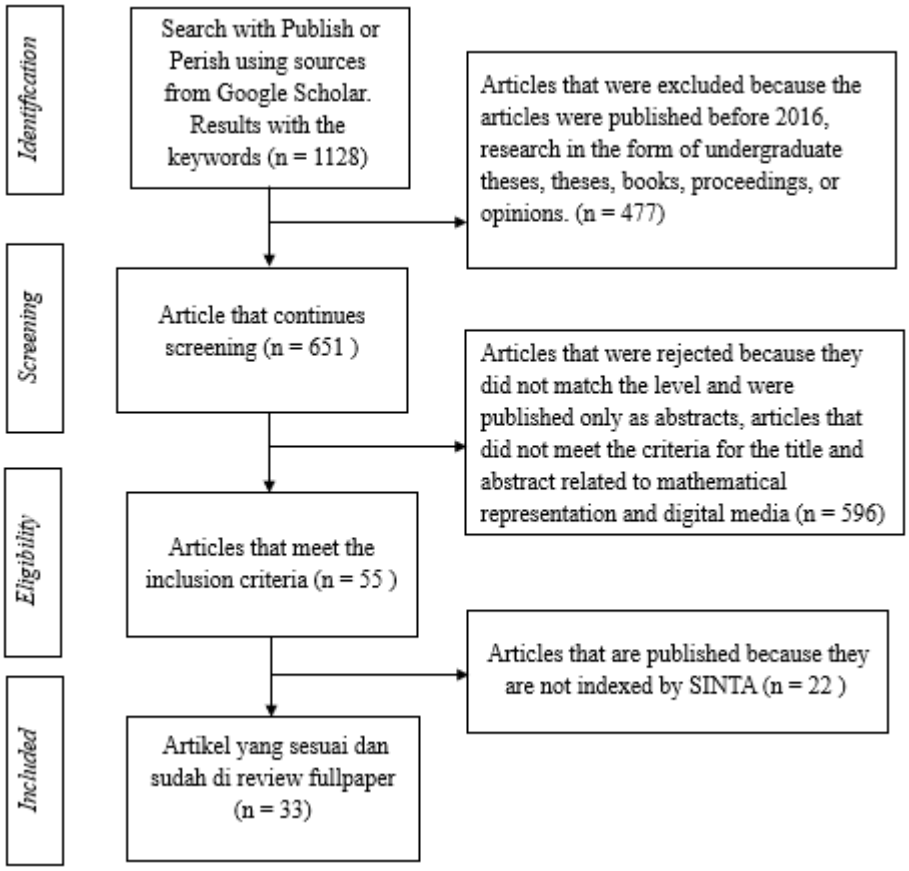
Table 1.
Inclusion and Exclusion Criteria of Articles

Inclusion	Exclusion
1. Articles published within the range of 2016–2025	1. Articles published before 2016
2. Articles indexed in SINTA	2. Articles not indexed in SINTA
3. Documents limited to scientific journal articles only	3. Documents in the form of theses, dissertations, books, proceedings, and opinion pieces
4. Articles published in full text	4. Articles published as abstracts only
5. Articles with student samples	5. Articles with samples of university students and teachers
6. Articles pertaining to Mathematical Representation and Digital Media	6. Articles pertaining to mathematics outside the scope of Mathematical Representation and Digital Media
7. Research articles conducted in Indonesia	7. Research articles conducted outside of Indonesia

The article selection process refers to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses procedure, which encompasses four core steps, namely identification, screening, eligibility assessment, and inclusion determination (Zega & Mendrofa, 2023). Based on this process, the research population was obtained in the form of

all articles discussing the use of digital learning media integrated with mathematical representation ability in Indonesia, with a total of 33 articles.

Figure 1.
PRISMA Flow Diagram



After conducting the selection process using the PRISMA procedure, the data obtained will subsequently be evaluated based on the following quality assessment criteria:

Q1: Does the journal paper state the rationale for selecting the digital learning media used to enhance students' mathematical representation ability?

Q2: Does the journal paper describe the educational level that serves as the subject of research on the use of digital learning media?

Q3: Does the journal paper explain the aspects of mathematical representation ability examined, such as visual, symbolic, or verbal representation?

3. Result and Discussion

Result

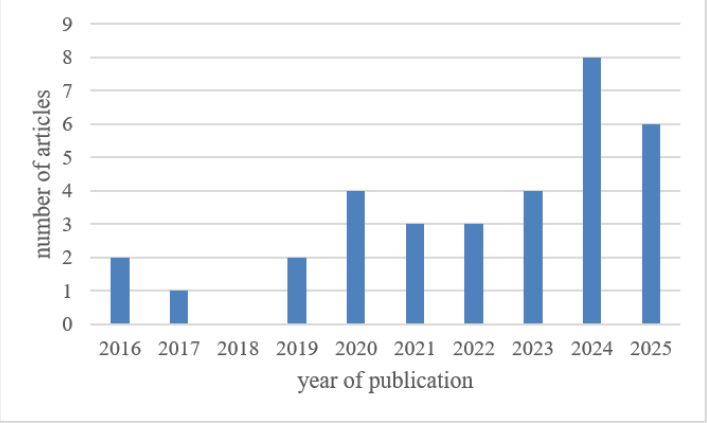
Table 2. *Quality Assessment Results*

Author and Year	Q1	Q2	Q3	Results
(Rahmadani, 2025)	✓	✓	✓	✓
(Widyasari, 2020)	✓	✓	✓	✓
(Payung dkk., 2025)	✓	✓	×	✓
(Riwayati dkk., 2023)	✓	✓	✓	✓
(Fatrina dkk., 2025)	✓	✓	✓	✓
(Laurence dkk., 2022)	✓	✓	×	✓
(Setiani & Hendikawati, 2024)	✓	✓	✓	✓
(Zega & Mendrofa, 2023)	✓	✓	✓	✓
(Hikmah dkk., 2019)	✓	✓	✓	✓
(Oktaria dkk., 2016)	✓	✓	✓	✓
(Kartina dkk., 2025)	✓	✓	✓	✓
(Murni dkk., 2024)	✓	✓	×	✓
(Salsabila dkk., 2023)	✓	✓	✓	✓
(Gustiana dkk., 2024)	✓	✓	✓	✓
(Annajmi, 2016)	✓	✓	✓	✓
(Nugroho, 2024)	✓	✓	✓	✓
(Rukiyah dkk., 2020)	✓	✓	✓	✓
(Dehani dkk., 2021)	✓	✓	×	✓
(Aulia dkk., 2025)	✓	✓	✓	✓
(Andriani dkk., 2021)	✓	✓	×	✓
(Lestari & Taqwani, 2024)	✓	✓	✓	✓
(F. Hidayat & Lestari, 2022)	✓	✓	✓	✓
(Elvina dkk., 2024)	✓	✓	✓	✓
(Wulandari, 2019)	✓	✓	✓	✓
(Gustin dkk., 2024)	✓	✓	✓	✓
(Amalia dkk., 2020)	✓	✓	×	✓
(Latifah & Sugiyantoro, 2025)	✓	✓	✓	✓
(Ilma & Turmudi, 2021)	✓	✓	✓	✓
(Fasa dkk., 2020)	✓	✓	×	✓
(Nuraeni dkk., 2022)	✓	✓	×	✓
(Sari dkk., 2018)	✓	✓	×	✓
(Septian dkk., 2023)	✓	✓	✓	✓
(Panjaitan & Siregar, 2024)	✓	✓	✓	✓

[RQ1] What Are the Research Trends in the Use of Digital Learning Media in Enhancing Students' Mathematical Representation Ability?

A publication trend analysis was performed to examine the evolution of research on the application of digital learning media in improving students' mathematical representation abilities from 2016 to 2025. Through the diagram, the tendencies and patterns of research development from year to year can be identified.

Figure 2.
Data by year of publication

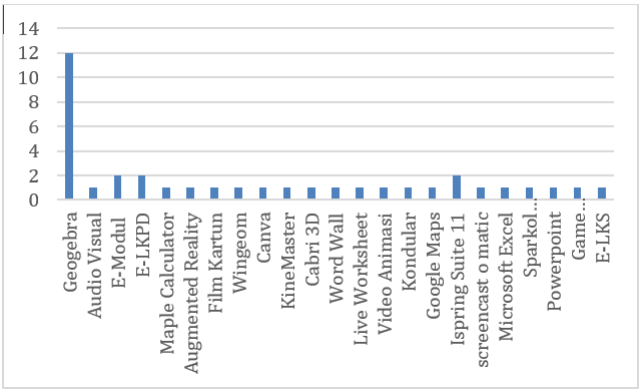


Based on the data, the number of article publications fluctuated from year to year, yet generally demonstrated an increasing trend, particularly during the 2024–2025 period. This surge may be influenced by several factors, such as the implementation of the Merdeka Curriculum, which emphasizes the use of technology and interactive learning, thereby further reinforcing the increase in research (Rahmadani, 2025)(Setiani & Hendikawati, 2024)(Kartina et al., 2025)(Murni et al., 2024)(Aulia et al., 2025). In addition, this trend is also supported by the increasingly accessible advancement of technology (Lestari & Taqwani, 2024)(Elvina et al., 2024)(Gustiana et al., 2024)(Gustin et al., 2024)(Latifah & Sugiyantoro, 2025)(Payung et al., 2025),which has attracted more researchers to examine this topic. This indicates that the utilization of digital learning media in supporting students' mathematical representation ability has increasingly become a focal point in mathematics education research.

[RQ2] What Types of Digital Learning Media Are Used to Enhance Students' Mathematical Representation Ability?

In the present systematic literature review, various types of learning media constitute one of the characteristics analyzed. Several types of learning media were identified in the data collection of this study, namely (1) Audio-Visual Media, (2) Digital Teaching Media, and (3) Interactive Multimedia.

Figure 3.
Data Based on Digital Learning Media

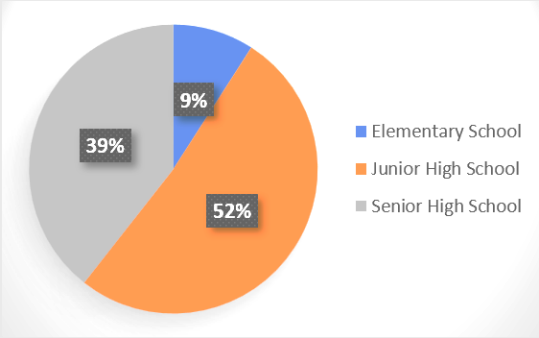


Based on the analysis of 33 articles, the use of digital learning media demonstrated variation across each subcategory. The most dominant media was GeoGebra, appearing in 12 articles (36%). Subsequently, several media were used in moderate quantities, such as Canva, E-LKPD, and iSpring Suite, each appearing in 2 articles (6%). Meanwhile, the majority of other media were used in relatively low frequencies, each appearing in only 1 article (3%). These findings indicate that although the types of media used are highly diverse, GeoGebra remains the most widely used media owing to its capability in visualizing mathematical concepts dynamically and interactively (Annajmi, 2016)(Amalia et al., 2020)(Ilma & Turmudi, 2021)(Fasa et al., 2020)(Panjaitan & Siregar, 2024)(Gustin et al., 2024).

[RQ3] At Which Educational Level Is Research on the Use of Digital Learning Media Most Frequently Conducted?

This study reveals differences in the use of learning media across various educational levels, as illustrated in Figure below.

Figure 4.
Data Based on Educational Level

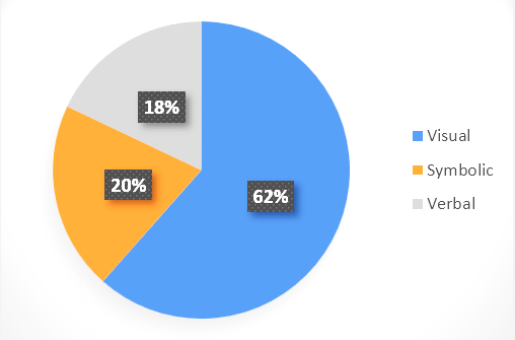


The figure reveals that Junior High School settings were the most frequently investigated contexts, which may be attributed to the critical role of this educational level in

fostering abstract thinking and advanced reasoning abilities. At this stage, students are beginning to develop abstract thinking ability, yet still require the support of visualization and representation to understand complex mathematical concepts, such as algebra and functions (Riwayati et al., 2023; Fatrina et al., 2025; Hikmah et al., 2019; Oktaria et al., 2016; Dehani et al., 2021; Andriani et al., 2021). This condition renders digital learning media a pedagogically relevant necessity, as it is capable of bridging the gap between concrete and abstract representation, yet such dominance also indicates an imbalance in research focus across educational levels. The scarcity of research at the Elementary School level suggests a tendency that learning is still facilitated through traditional concrete media, even though digital technology has the potential to present concepts in a more interactive and contextual manner, while the limited research at the Senior High School level reflects the assumption that students are already capable of thinking abstractly on their own, despite the fact that the subject matter being studied is increasingly complex and requires multi-level representation.

[RQ4] Which Aspects of Mathematical Representation Ability Are Most Dominantly Examined in the Research?

Figure 5.
Data Based on Aspects of Mathematical Representation



Based on the figure, research on mathematical representation ability is more dominantly focused on the aspect of visual representation compared to symbolic and verbal representation. The analysis reveals that a large portion of the existing literature tends to focus on visual representations in mathematics, with many studies highlighting how students use figures, graphs, and tables to express their mathematical thinking. Symbolic and verbal representations, on the other hand, receive comparatively less attention. This tendency toward visual representation in research is likely shaped by the nature of digital learning media itself, which generally lends itself more naturally to dynamic visual presentations — think animations, interactive graphs, and simulations. (Rahmadani, 2025)(Widyasari, 2020)(Wulandari, 2019)(Sari et al., 2018). Media such as GeoGebra, for instance, directly facilitates the visualization of mathematical concepts, making it easier to observe its impact on students' understanding (Nugroho, 2024)(Septian et al., 2023). From a methodological perspective, visual representation also tends to be easier to measure than its symbolic and

verbal counterparts, which likely explains why researchers gravitate toward it more often as a research focus.

Discussion

A synthesis of the 33 selected articles shows that the use of digital learning media generally has a positive impact on students' mathematical representation ability. Most studies indicate that digital media help students understand mathematical concepts more concretely through visualization, interactivity, and systematic presentation of material, while also enhancing learning motivation, student engagement, and mathematics learning outcomes.

The review reveals a shift in research trends over time. During 2016–2020, research focused predominantly on mathematical visualization software such as GeoGebra and Cabri 3D, which were mainly used for geometry and spatial visualization topics. During 2021–2025, research shifted toward more varied and integrated media, such as E-Modules, E-LKPD, Canva, iSpring Suite, and animated videos, indicating a move toward more flexible, interactive, and student-centered learning development.

It is worth noting that media based on more advanced technologies, such as AI, VR, AR, gamification, and adaptive learning, were almost entirely absent throughout 2016–2025. This absence may be related to several factors: limited cost and infrastructure (specialized devices, stable internet, licensing) that remain unevenly distributed across Indonesian schools (Maulida et al., 2025); limited teacher readiness to integrate AI- or adaptive-system-generated feedback into instruction (Haryudita & Noer, 2024); a national curriculum and assessment system that remains oriented toward conventional formats; and facility constraints such as limited computer laboratories and uneven student device ownership. Accordingly, the dominance of GeoGebra may reflect accessibility and institutional readiness more than inherent pedagogical superiority. This implies that policy intervention and teacher training aimed at closing the access gap may be a necessary precondition before greater diversification of media types can be realized.

The cross-analysis indicates a relationship between media type and the aspect of mathematical representation developed. Visual media such as GeoGebra, Cabri 3D, and animated videos tend to support visual representation, whereas E-Modules, E-LKPD, and Canva/iSpring-based multimedia more often support symbolic and verbal representation through the systematic presentation of problem-solving steps. In addition, dynamic visual media are more widely used at the elementary and early junior high school levels, while GeoGebra and simulation-based media are more dominant at the junior and senior high school levels for understanding abstract concepts such as functions and geometric transformations.

The dominance of junior high school may be related to its curriculum content, which includes a substantial amount of material well suited to dynamic visualization (functions, coordinate geometry, algebra). Conversely, the scarcity of research at the elementary level may be attributable to young learners limited digital literacy, while the scarcity at the higher education level may reflect a research tendency to treat mathematical representation primarily as a K-12 pedagogical concern rather than one relevant to more abstract, advanced mathematics. This imbalance suggests that current research priorities may

be shaped more by convenience and curriculum alignment than by genuine pedagogical need, indicating that the elementary and higher education levels still warrant greater attention.

From a pedagogical standpoint, the dominance of GeoGebra can be explained through Cognitive Load Theory, which posits that learning is more effective when extraneous cognitive load is minimized through simple, easily processed visual information (Richardo, 2021). This finding also reinforces Bruner's representation theory regarding the enactive, iconic, and symbolic stages (Fauziati, 2021), in which dynamic visual media support iconic representation, while E-Modules and E-LKPD support symbolic and verbal representation.

However, both theories are essentially medium-agnostic — the same principles could equally justify the use of AR for enactive-to-iconic transitions or AI-adaptive systems for personalized symbolic scaffolding. This suggests that GeoGebra's dominance in the literature may be driven more by its low cost, open-source availability, and low technical barrier for teachers and researchers than by any inherent theoretical superiority. In other words, GeoGebra's dominance should be interpreted as a reflection of current resource constraints rather than evidence that it is the optimal medium.

In terms of effectiveness, no single type of media was found to be most effective across all aspects of mathematical representation: GeoGebra was more effective for visual-spatial representation, E-Modules and E-LKPD for symbolic-procedural representation, while audio-visual media were more suitable for supporting foundational concept understanding among younger students. The effectiveness of digital learning media is therefore contextual, depending on learning objectives and student characteristics.

Although research on visual representation is fairly dominant, verbal representation remains relatively underexplored, despite the fact that the ability to explain mathematical ideas orally and in writing is an important part of students' mathematical communication and reasoning. This points to a research gap that warrants further development in future studies, for example through features supporting written explanation, digital discussion, or technology-based verbal presentation.

These findings carry implications for three groups of stakeholders. For teacher professional development, there is a need to move beyond training focused on a single dominant tool (GeoGebra) toward broader digital pedagogical competence. For policymakers, closing the infrastructure and cost gap may be a precondition before the benefits of AI-adaptive learning and AR/VR can be empirically realized in Indonesian classrooms. For researchers, the concentration of studies on GeoGebra and on the junior high school level signals a need for a more balanced research agenda that also addresses verbal representation, the elementary level, and higher education, so that the existing evidence base does not reinforce a narrow view of the potential of digital learning media.

Overall, digital learning media make an important contribution to supporting the development of students' mathematical representation ability. However, their implementation needs to account for the fit between media type, the aspect of mathematical representation, subject matter, and educational level in order to be optimally aligned with students' learning needs. For teachers, these findings provide practical guidance for selecting digital learning media that align with students' educational level, learning objectives, and the aspects of

mathematical representation to be developed. For educational media developers, the findings highlight the importance of designing digital learning media that integrate visual, symbolic, and verbal representations while taking into account curriculum requirements and learners' characteristics. For future researchers, this review identifies opportunities to investigate underexplored types of digital learning media, educational levels, and aspects of mathematical representation, particularly verbal representation. In addition, future studies are encouraged to conduct experimental or meta-analytic research to provide stronger empirical evidence regarding the effectiveness of digital learning media in supporting students' mathematical representation ability.

4. Conclusion

This systematic review of 33 articles shows that digital learning media contribute positively to students' mathematical representation ability, with usage patterns shifting from visualization tools such as GeoGebra during 2016–2020 toward more integrated media such as E-Modules and E-LKPD during 2021–2025. However, a more substantial finding lies in the gap behind this pattern: advanced technologies such as AI, VR, AR, gamification, and adaptive learning are almost entirely absent from the literature, while research remains concentrated on the junior high school level and on visual representation. Theoretically, this review shows that Cognitive Load Theory and Bruner's representation theory—commonly used to explain the effectiveness of media—are less adequate for explaining patterns of media adoption, as both theories are essentially medium-agnostic. This review offers an additional perspective, suggesting that adoption patterns of digital learning media need to be understood as the result of an interaction between pedagogical and structural factors—accessibility, cost, teacher readiness, and curriculum alignment—thereby extending existing representation theory frameworks by incorporating the dimension of the technology-access gap.

Practically, these findings point to three recommendations: strengthening teachers' digital competence in ways that are not centered on a single dominant tool; equitable distribution of infrastructure and funding as a precondition before more advanced technologies can be widely implemented; and expanding the space for technology-based approaches within the curriculum and assessment system. Given that this review relied solely on the Google Scholar database and covered 33 articles within the 2016–2025 timeframe, generalization of these findings should be made with caution. Future research is recommended to broaden the search databases used and to direct greater attention toward verbal representation, the elementary and higher education levels, and the feasibility of implementing advanced technologies within the context of resource constraints in Indonesia.

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