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The Role of Technology-Based Multirepresentations in Enhancing Students' Understanding of Mathematical Concepts: A Systematic Literature Review

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ABSTRACT

Understanding mathematical concepts is a fundamental ability that enables students to navigate and connect abstract mathematical ideas. However, mathematics' inherently abstract nature often creates challenges in the learning process. One promising approach is using technology-based multiple representations. This study aims to synthesize the pedagogical role of technology-based multiple representations in supporting students' conceptual understanding of mathematics. Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework, a manual literature search was conducted via Google Scholar in June 2026 using Indonesian keywords without Boolean operators, yielding 688 initial records. After systematic screening and critical quality appraisal against predefined eligibility criteria, 12 primary SINTA-indexed journal articles (2018–2026) were included in the narrative synthesis. The findings show that GeoGebra is the most widely used technology (appearing in 9 of 12 studies), while visual-graphical and symbolic formats are the most frequently integrated representational modes. Grounded in the cognitive functions dimension of the Design, Functions, Tasks (DeFT) framework, technology-based multiple representations primarily facilitate three operational indicators of conceptual understanding: presenting concepts through various representations (I4), selecting and executing procedures with reasoning (I5), and applying concepts to problem-solving tasks (I6). The main conclusion indicates that the educational utility of digital media relies not on the software in isolation, but on its pedagogical capacity to weave diverse representational modes into a cohesive cognitive structure.

Keywords: Learning Technology; Multiple Representations; Systematic Literature Review; Understanding Mathematical Concepts

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INTRODUCTION

Mathematics instruction is not merely oriented toward procedural execution and mechanical calculation; rather, it emphasizes conceptual understanding as the primary foundation for building meaningful mathematical knowledge (Ramadhani & Mulbar, 2026). Nevertheless, many students across educational levels consistently perceive mathematics as a difficult subject (Putri & Pasandaran, 2024). This difficulty stems from mathematics' abstract structure, which requires students to construct mental models that link formal symbolism with spatial and visual representations (Fitria et al., 2022; Ramadhani & Mulbar, 2026). Consequently, while many students can solve routine problems by following memorized algorithms, they face cognitive obstacles when confronted with non-routine problems that require flexible application of concepts (Nurdin et al., 2019; Siregar, 2021).

Understanding mathematical concepts involves grasping fundamental principles, recognizing structural relationships between concepts, and transferring knowledge to solve non-routine tasks (Cahyanti et al., 2023; Santosa et al., 2025). Operationalizing conceptual understanding requires clearly distinguishing it from procedural fluency: procedural fluency is limited to accurately executing algorithmic steps. In contrast, conceptual understanding reflects the underlying cognitive schema that justifies why those procedures are valid. Students with a strong grasp of mathematical concepts can interpret mathematical information efficiently, translate between different forms of representation, and select optimal problem-solving strategies. Conversely, a weak grasp of concepts fosters a reliance on rote memorization, diminishes self-confidence, and triggers learning anxiety (Nurhairunnisah & Sujarwo, 2018).

A primary factor contributing to a poor grasp of concepts is students' limited multirepresentational ability, an internal cognitive construct that enables them to understand, construct, and flexibly translate between various forms of mathematical representation (Budarsini et al., 2018; Setiani & Hendikawati, 2024). In this context, mathematical representations refer to external modes for presenting mathematical ideas (such as verbal explanations, formal algebraic symbols, and coordinate graphs). At the same time, interactive media features serve as a technological intermediary that facilitates translation between these modes. To qualify as technology-based multirepresentation, a digital learning environment must dynamically display at least two distinct forms of representation for the same concept and support real-time translation or linkage between them; the mere presence of static images and text side by side on a digital screen does not meet this criterion. When dynamic software lets students link changes in symbolic equations directly to graphical displays in real time, it bridges abstract symbolism with visual intuition (Khotimah et al., 2022; Widiyanti et al., 2021). Conversely, conventional instruction, which relies heavily on presenting static, isolated symbols, often due to time constraints, fails to provide the dynamic translation students need to construct comprehensive cognitive schemas.

Digital technology offers new opportunities for implementing multirepresentation by providing a dynamic, interactive, and interconnected learning environment (Fauzi et al., 2026). Interactive technology enables students to observe the relationships between representations in real time, explore concepts independently, and receive immediate feedback (Margareta & Karimah, 2025). Nevertheless, the pedagogical impact varies depending on the media's level of interactivity and feedback mechanisms. Interactive dynamic software such as GeoGebra applets, Wolfram Alpha, and virtual manipulatives allows for direct manipulation, where student input instantly updates the corresponding visual and symbolic representations (Aien et al., 2025; Cahyani et al., 2025; Putri & Pasandaran, 2024; Yanti et al., 2019). Conversely, dynamic video media (such as GeoGebra screen recordings) show animated connections between representations without direct user manipulation. However, they still improve

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conceptual understanding as shown by post-test performance compared with conventional instruction (Nurdin et al., 2019). Furthermore, tools like Photomath support procedural-conceptual reflection through step-by-step symbolic interpretation (Aminullah, 2025), while interactive web-based platforms facilitate enhanced conceptual understanding across various educational levels (Anshari & Siregar, 2026; Fadilah et al., 2023; Romadhani & Harahap, 2022).

Nevertheless, existing literature reviews remain limited in scope regarding the interplay between digital media, multi-representational relationships, and cognitive indicators. Previous systematic reviews have largely focused either on the general effectiveness of digital media without isolating multi-representational mechanisms or on multi-representational learning within the broad context of STEM, and have not mapped these findings to specific cognitive indicators of mathematical conceptual understanding. For instance, earlier reviews have examined the use of individual dynamic geometry software or the broader integration of digital media. However, they often treat "conceptual understanding" as a monolithic learning outcome rather than evaluating its distinct cognitive indicators.

This study addresses this gap by synthesizing empirical literature on technology-based multirepresentation specifically, approaches that explicitly link at least two dynamic formats to support understanding of mathematical concepts. Guided by the Design, Functions, Tasks (DeFT) framework (Ainsworth, 2006), this Systematic Literature Review (SLR) breaks down the primary research question into three structured sub-questions:

1. What are the characteristics of the studies, mathematical content, and dynamic technological media employed in empirical literature?
2. Which cognitive indicators of mathematical conceptual understanding are most prominently facilitated by technology-based multi-representation?
3. How does technology-based multi-representation facilitate conceptual understanding when examined through the lens of the cognitive function dimension of the DeFT framework?

METHOD

Research Design and Setting

This study uses a Systematic Literature Review (SLR) methodology to identify, evaluate, and synthesize empirical research on technology-based multirepresentations and mathematical concept understanding. To ensure transparent, structured reporting, this review protocol follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Page et al., 2021). The review was conducted following an unregistered protocol, organized into six operational stages: (1) formulation of research questions, (2) database search strategy, (3) screening and eligibility assessment of primary studies, (4) critical quality appraisal, (5) data extraction, and (6) qualitative narrative synthesis. Guided by the Design, Functions, Tasks (DeFT) framework (Ainsworth, 2006), this review protocol was implemented to address the three sub-research questions formulated in the Introduction.

Participants, Instruments, and Procedures

A comprehensive literature search was conducted manually in June 2026 directly using the Google Scholar search engine. To ensure full transparency and replicability, the search was executed using natural-language Indonesian search terms without Boolean operators. The exact search keywords entered into the search interface were: "Multiple representations, learning technology, understanding of

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mathematical concepts, interactive digital media". Search limiters were set to custom publication years between 2018 and 2026, targeting open-access journal articles published in Indonesian or English. Search results were sorted by relevance. Given the interface constraints of manual Google Scholar retrieval, the top 10 search result pages (comprising 100 records per query iteration) were thoroughly screened, yielding an initial total of 688 records. We manually extracted all identified metadata into a structured spreadsheet for screening.

Google Scholar was selected due to its comprehensive coverage of national SINTA-indexed journals that are frequently omitted from commercial international databases. However, relying on manual retrieval using only Indonesian keywords without Boolean operators in SINTA-indexed journals may miss unindexed studies or broader international literature, which is explicitly acknowledged as a methodological limitation of this review.

Table 1. Inclusion and Exclusion Criteria for Literature Screening

Criterion	Inclusion Criteria	Exclusion Criteria	Justification & Methodological Purpose
Topic & Domain	Empirical studies focusing explicitly on mathematics education (elementary, secondary, or tertiary level).	Studies focusing on general STEM, physics (e.g., basic physics), chemistry, engineering, or non-mathematical domains.	Ensure synthesis integrity by restricting scope strictly to mathematical conceptual understanding.
Intervention & Technology	Digital media featuring technology-based multiple representations displaying at least two distinct formats dynamically linked with real-time translation (e.g., GeoGebra applets, Wolfram Alpha, interactive dynamic graphics).	Static digital presentations (e.g., static images paired with text on PDF/PPT slides) or non-interactive media without real-time dynamic linkages.	Adheres strictly to the operational definition of dynamic technology-based multirepresentations.
Outcome Variable	Measures or reports specific cognitive indicators of mathematical conceptual understanding (I1-I6) via post-test scores, gain, or descriptive cognitive profiles.	Focuses exclusively on non-conceptual constructs (e.g., generic problem-solving, critical thinking, affective engagement, or mathematical anxiety) without measuring concept indicators.	Isolates conceptual understanding from broader affective or general cognitive outcomes.
Study Design	Empirical research designs include quasi-experimental or qualitative-descriptive empirical studies.	Non-empirical papers, theoretical reviews, opinion pieces, commentary articles, or meta-analyses.	Allows broad qualitative narrative synthesis while classifying empirical evidence strength based on design.
Publication Type & Peer Review	Original research articles published Original research articles published in peer-reviewed scholarly journals (SINTA-indexed national journals or open access international journals).	Conference proceedings, book chapters, dissertations, theses, working papers, or non-peer-reviewed repositories.	Guarantees quality appraisal standards across all synthesized primary literature.
Language & Time Frame	Articles published in English or Indonesian between 2018 and 2026.	Articles published before 2018 or written in languages other than English or Indonesian.	Captures the most recent 8 years of empirical developments in digital learning technologies.

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Study quality was evaluated using a standardized 8-item appraisal checklist adapted from the Joanna Briggs Institute (JBI) tools for educational research (Aromataris dkk., 2024). Publication venue indexing (1 article in SINTA 2, 3 in SINTA 3, and 8 in SINTA 4) was recorded purely as contextual reporting rather than a proxy for individual study quality. Lower quality appraisal scores in pre-experimental studies (primarily due to the lack of control groups) were accounted for during synthesis by tempering causal assertions. The complete selection workflow, from the initial retrieval ($N = 688$), duplicate removal ($n = 124$), title/abstract screening ($n = 564$), full-text eligibility assessment ($n = 64$), to final inclusion ($n = 12$), is presented in the PRISMA 2020 flow diagram (**Figure 1**).

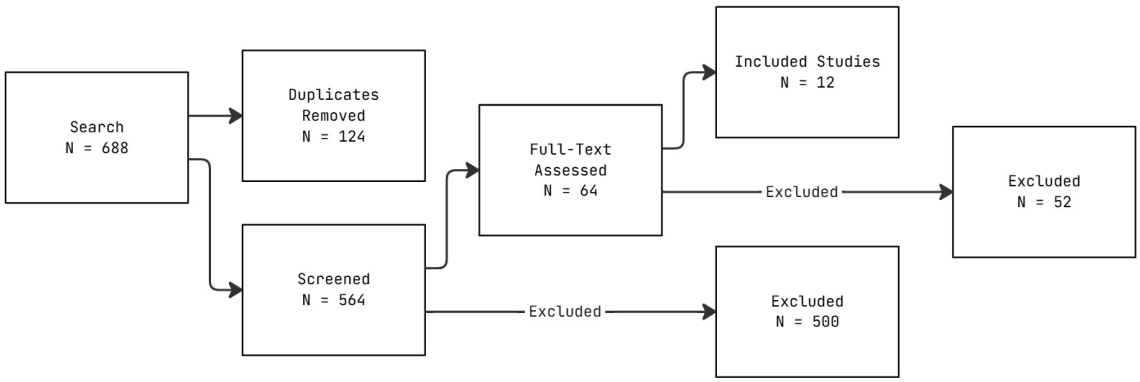

Figure 1. PRISMA flow diagram for the article selection process

Data Analysis

Data from the 12 primary articles included were analyzed using a thematic synthesis technique. Content extraction focused on the digital technologies employed, the target mathematical subject matter, the forms of representation, the research design, and the reported indicators of conceptual understanding. To eliminate coding ambiguity and ensure 100% internal consistency across the tables, results, discussion, and conclusions, the analytical framework explicitly established six active operational indicators (I1–I6), adapted from (Fitria et al., 2022), namely: (I1) restating concepts, (I2) classifying objects based on specific properties, (I3) providing examples and non-examples of a concept, (I4) presenting concepts through various mathematical representations, (I5) selecting and using specific procedures or operations, and (I6) applying concepts to problem-solving. The theoretical indicator concerning the "development of necessary and sufficient conditions" was excluded from the operational coding framework from the outset, as it did not appear in the primary empirical literature. Furthermore, this review strictly distinguishes between indicators that were not reported by the authors of the primary studies and those that were not facilitated by the interventions themselves. The synthesis results were subsequently interpreted through the "Functions" (cognitive functions) dimension of the Design, Functions, Tasks (DeFT) framework (Ainsworth, 2006).

RESULTS

A detailed thematic synthesis of the 12 included primary studies is presented in Table 2. To enable readers to assess the comparability across studies critically, Table 2 outlines key research characteristics, including sample size (*N*), target educational level, research design (e.g., quasi-experimental, pre-experimental, or qualitative-descriptive), intervention duration, comparison/control groups, and the

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primary outcomes reported by the authors of the primary studies. Furthermore, to ensure analytical clarity, empirical findings reported directly by the primary studies, such as post-test scores, N-gain calculations, or qualitative profile observations, are strictly distinguished from the reviewer's theoretical interpretations regarding the dimensions of cognitive functions within the Design, Functions, Tasks (DeFT) framework (Ainsworth, 2006). The mapping of specific indicators (I1–I6) is supported by references to explicit evidence and brief excerpts from the primary articles.

Table 2. Technology-Based Multirepresentational Article Synthesis

Author & Year	Journal	Focus, Tech & Representation	Methodology & Primary Findings	Facilitated Indicators & DeFT Synthesis
(Aminullah, 2025)	Mandalika Mathematics and Education Journal (SINTA 3)	**Focus:** Quadratic Equations **Tech:** Photomath **Mode:** Visual, Verbal, Symbolic	**Sample/Design:** $N = 32$ (Grade 9) Pre-experimental **Outcome:** Post-test mean 82.5; significant procedural increase.	(I1, I5) *Complementary Role*: Bridges procedural execution with symbolic meaning.
(Putri & Pasandaran, 2024)	Pedagogy: Jurnal Pendidikan Matematika (SINTA 4)	**Focus:** Geometric Transformation **Tech:** GeoGebra **Mode:** Visual-Graphical, Symbolic	**Sample/Design:** N=64 (Grade 11) Quasi-experimental **Outcome:** Exp. $N-Gain = 0.7$ vs 0.4 ($p < 0.0$).	(I2, I4, I5) *Constraining Role*: Visual shifting limits coordinate matrix misconceptions.
(Silvina et al., 2025)	Jurnal Pendidikan Matematika Universitas Lampung (SINTA 4)	**Focus:** Equations of Straight Lines **Tech:** GeoGebra, PowerPoint, Animation **Mode:** Visual-Graphical, Verbal, Symbolic	**Sample/Design:** $N = 68$ (Grade 8) Quasi-experimental **Outcome:** Exp. Mean (84.2) significantly outperformed (69.5).	(I4, I5) *Constructing Role*: Slope animation integrates gradient changes with algebra.
(Santosa et al., 2025)	AKSIOMA: Jurnal Matematika dan Pendidikan Matematika (SINTA 4)	**Focus:** Geometric Transformations **Tech:** Canvas LMS-based, using GeoGebra **Mode:** Visual-Graphical, Verbal, Symbolic	**Sample/Design:** $N = 70$ (Grade 11) Quasi-experimental **Outcome:** Significant difference in post-test scores ($p = 0.00$)	(I4, I5, I6) *Constructing Role*: Dynamic dragging aids coordinate translation and problem solving.
(Cahyani et al., 2025)	Griya Journal of Mathematics Education and Application (SINTA 4)	**Focus:** 3D Spatial Geometry **Tech:** GeoGebra 3D **Mode:** Visual-Graphical, Symbolic	**Sample/Design:** $N = 35$ (Grade 12) Pre-experimental **Outcome:** Post-test mean increased from 52.1 to 81.4 (85.7% mastery).	(I2, I4) *Complementary Role*: 3D rotation visualizes nets alongside equations.
(Suryawan & Permana, 2020)	PRISMA (SINTA 3)	**Focus:** 3D Curved Surface Shapes **Tech:** GeoGebra & Schoology **Mode:** Visual-Graphical, Verbal, Symbolic	**Sample/Design**: $N = 60$ (Grade 9) Quasi-experimental **Outcome:** Exp. $N-Gain = 0.6$ vs 0.4.	(I2, I4, I5) *Constraining Role*: Surface manipulation strengthens geometric property recognition.
(Nurdin et al., 2019)	Jurnal Riset Pendidikan Matematika (SINTA 2)	**Focus:** Transformation Geometry **Tech:** GeoGebra Video	**Sample/Design:** $N = 62$ (SMK) Quasi-experimental **Outcome:** Exp. Mean (78.4) significantly	(I4, I5) *Complementary Role*: Animated video links visual movement with matrix steps.

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		Mode: Visual-Graphical, Verbal, Symbolic	higher than (63.2); $p <$ 0.0.	
(Yanti et al., 2019)	AKSIOMA: Jurnal Matematika dan Pendidikan Matematika (SINTA 4)	**Focus:** Linear Programming **Tech:** GeoGebra Applet **Mode:** Visual-Graphical, Symbolic	**Sample/Design:** $N = 58$ (Grade 11) Quasi-experimental **Outcome:** Exp. $N - Gain$ (78.4) significantly higher than (0.3).	(I4, I5) *Constructing Role*: Graph shading links inequalities directly to solution regions.
(Aien et al., 2025)	Kognitif: Jurnal Riset HOTS Pendidikan Matematika (SINTA 4)	**Focus:** Transformation Geometry **Tech:** GeoGebra **Mode:** Visual-Graphical, Symbolic	**Sample/Design:** $N = 30$ (Grade 11) Pre-experimental **Outcome:** Post-test score improved from 45.3 to 79.8 ($p > 0.0$).	(I2, I4) *Constraining Role*: Object drag-and-drop links visuals with symbolic rules.
(Nay & Maure, 2020)	Asimtot: Jurnal Kependidikan Matematika (SINTA 3)	**Focus:** Algebraic Operations **Tech:** Virtual Manipulatives **Mode:** Visual, Verbal, Symbolic	**Sample/Design:** $N = 45$ (Grade 7) Quasi-experimental **Outcome:** Exp. Score (81) significantly higher than (67)	(I1, I3, I4) *Complementary Role*: Virtual tile manipulation transforms abstract algebra into concrete tiles.
(Hutajulu & Soesanto, 2023)	Delta: Jurnal Ilmiah dan Pendidikan Matematika (SINTA 4)	**Focus:** Power Numbers and Root Forms **Tech:** GeoGebra **Mode:** Visual-Graphical, Symbolic	**Sample/Design:** $N = 36$ (Grade 10) Pre-experimental **Outcome:** Pass rate reached 83.3% with a mean score of 79.5.	(I4, I5) *Constructing Role*: Graph exploration leads to structural exponent discovery.
(Khotimah et al., 2022)	Imajiner: Jurnal Matematika dan Pendidikan Matematika (SINTA 4)	**Focus:** Polyhedra **Tech:** Wolfram Alpha **Mode:** Visual-Graphical, Verbal, Symbolic	**Sample/Design:** $N = 32$ (Grade 8) Qualitative-Descriptive **Outcome:** Descriptive profile 78% successfully generated 3D visual & symbolic models.	(I4, I5) *Descriptive Proof*: Combines 3D rendering and algebraic input to map profiles.

The primary synthesis reveals that GeoGebra is the most widely used technology, appearing in 9 of the 12 primary studies (as standalone software, applets, 3D dynamic tools, Canvas LMS integrations, or recorded video demonstrations). To maintain transparency, primary studies incorporating multi-tool setups (Silvina et al., 2025) using GeoGebra alongside PowerPoint and animated video were included under each constituent technology category while maintaining the primary study as a single unit of analysis ($N = 12$). Other technological tools evaluated include Photomath, Wolfram Alpha, virtual manipulatives, and web-based platforms. The study examines geometric topics (e.g., transformations, 3D geometry, curved-surface solids) and algebraic domains (e.g., quadratic equations, linear programming, exponential properties).

In terms of representational modes, visual-graphical formats (dynamic 3D models, coordinate planes, animated diagrams) and symbolic formats (algebraic equations, matrices, inequalities) were regularly integrated across all 12 studies, supported by verbal explanations. Rather than making a uniform causal claim, empirical evidence must be interpreted through the lens of study designs and analytical heterogeneity:

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- Quasi-Experimental Studies ($n = 7$): Studies using active control groups (Putri & Pasandaran, 2024; Santosa et al., 2025; Suryawan & Permana, 2020; Yanti et al., 2019) reported significant advantages ($p < 0.05$) for interactive multirepresentational groups over conventional instruction, yielding N-gain scores in the high (0.71) to moderate ($0.65 - 0.68$) ranges compared to control groups ($0.38 - 0.45$).
- Pre-Experimental Studies ($n = 4$): Single-group pre/post-test designs (Aien et al., 2025; Cahyani et al., 2025; Hutajulu & Soesanto, 2023) demonstrated significant pre-to-post mean gains and classical completeness (83.3%), although these designs inherently carry internal validity limitations due to the absence of a control group.
- Qualitative-Descriptive Studies ($n = 1$): Khotimah et al. (2022) provided descriptive profile evidence showing that 78% of students generated dynamic 3D visual and symbolic representations using Wolfram Alpha, without testing interventional causality (I6, present in 3 studies).

DISCUSSION

The selected literature suggests that technology-based multiple representations generally support students' mathematical conceptual understanding. However, because the technological tools in the reviewed studies were integrated alongside specific instructional models, teacher practices, diverse tasks, and varying intervention durations, this review cannot isolate the standalone causal effect of technology itself. The observed learning improvements are driven by the combined pedagogical ecosystem rather than the isolated technical sophistication of a digital medium. Interactive software such as GeoGebra and Wolfram Alpha enables students to manipulate representational parameters, such as shifting a geometric vertex or modifying equation coefficients, and observe instantaneous, real-time updates in corresponding visual displays (Putri & Pasandaran, 2024; Santosa et al., 2025).

To analyze these dynamic interactions, this review explicitly focuses on the cognitive Functions dimension of (Ainsworth, 2006) Design, Functions, Tasks (DeFT) framework. The DeFT framework offers a theoretical structure to interpret how dynamic representations support learning across three cognitive functions:

1. **Complementary Roles**: Visual and verbal formats complement formal symbolic expressions. Theoretically, this arrangement may lower extraneous cognitive load by providing concrete visual scaffolding (Nay & Maure, 2020). However, because cognitive load was not empirically measured in the primary studies, this remains a hypothesized theoretical mechanism. In fact, if learners are required to split their attention between multiple uncoordinated displays, split-attention effects could significantly increase cognitive load.
2. **Constraining Interpretation**: Dynamic visual rendering limits misinterpretations of abstract symbols. In the primary literature, real-time visual feedback supported students in classifying geometric objects (I2, present in 4 studies) and recognizing non-examples (I3, present in 1 study) (Aien et al., 2025; Cahyani et al., 2025).
3. **Constructing Deeper Understanding**: Simultaneous translation across representational formats facilitates cognitive abstraction. In interventional studies assessing problem-solving (I6, present in 3 studies), dynamic linking helps students translate problem conditions into mathematical procedures (I5, present in 9 studies) and solve routine to non-routine tasks, such as contextual optimization in linear programming (Santosa et al., 2025; Silvina et al., 2025).

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The reporting frequency of operational indicators, led by presenting concepts through various representations (I4, 11 studies), followed by selecting/using procedures (I5, 9 studies), classifying objects (I2, 4 studies), applying concepts to problem-solving (I6, 3 studies), restating concepts (I1, 2 studies), and providing examples/non-examples (I3, 1 study), reflects the empirical coverage of the current literature rather than direct causal evidence. Technology reduces translation friction between symbolic and visual domains, encouraging students to build interconnected mental schemas (Aminullah, 2025; Hutajulu & Soesanto, 2023).

CONCLUSION

This systematic literature review indicates that technology-based multiple representations hold positive potential for facilitating students' mathematical conceptual understanding. Across the 12 reviewed primary studies, GeoGebra emerged as the most frequently reported technological tool, predominantly integrating visual-graphical and symbolic representational formats. Within the methodological constraints and design heterogeneity of the available evidence, ranging from descriptive profiles to quasi-experiments, this approach primarily supported students' ability to present concepts across various representational forms (I4), select and use procedural operations with conceptual justification (I5), and apply concepts to problem-solving (I6). The main conclusion is that the educational value of digital tools does not come from software features alone, but from their pedagogical capacity to weave diverse representational modes into a coherent cognitive framework. For instructional practice, educators should design technology-integrated tasks that explicitly prompt students to translate between dynamic visual models and symbolic expressions, requiring written or verbal explanations of the linkages rather than passive media consumption.

This research has several limitations. First, the search strategy relied exclusively on Google Scholar (a broad academic search engine rather than a dedicated national database). It was limited to open-access SINTA-indexed journals, which may omit unindexed national studies or international literature. Second, high heterogeneity in research designs (ranging from qualitative profiles to quasi-experiments), potential publication bias toward positive outcomes, and inherent subjectivity in primary data coding present analytical constraints. Future research should use multi-database retrieval and incorporate empirical cognitive load assessments. Methodological Rigor and Retention: Conduct randomized controlled trials or rigorous quasi-experiments with delayed posttests to evaluate long-term concept retention—a critical dimension currently unmeasured in the primary literature. Cognitive Load and Comparative Designs: Incorporate direct empirical measures of cognitive load to determine when multi-representational displays support schema acquisition versus cause split-attention friction. Targeted Spatial Technologies: Evaluate emerging spatial tools (such as Augmented Reality or AI-driven adaptive platforms) specifically to address 3D spatial visualization gaps identified in this review, rather than implementing technology for novelty alone.

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DECLARATIONS

Author Contributions: Ayu Lestari: Conceptualization, literature search, data analysis, and original draft preparation. Hepsi Nindiasari: Supervision, methodology, and validation. Ria Sudiana: Supervision, validation, and manuscript review. All authors approved the final manuscript.

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Data Availability: Data from the 12 reviewed studies are summarized in the manuscript. Additional supporting data are available from the corresponding author upon reasonable request.

Conflict of Interest: The authors declare no conflicts of interest.

Use of Generative AI: The authors declare that no generative AI tools were used in preparing this manuscript.

REFERENCES

Aien, N., Laswadi, L., & Sari, M. (2025). Penggunaan Aplikasi Geogebra dalam Pembelajaran Matematika terhadap Kemampuan Pemahaman Konsep dan Minat Belajar Siswa. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *5*(1), 71–87. https://doi.org/10.51574/kognitif.v5i1.2755

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16*(3), 183–198. https://doi.org/10.1016/j.learninstruc.2006.03.001

Aminullah, A. (2025). Dinamika Pemahaman Konseptual Siswa dalam Pembelajaran Matematika Berbantuan Photomath. *Mandalika Mathematics and Educations Journal*, *7*(4), 2041–2051. https://doi.org/10.29303/jm.v7i4.10599

Anshari, F., & Siregar, B. H. (2026). Pengembangan media pembelajaran matematika berbasis pendekatan deep learning melalui google sites untuk meningkatkan pemahaman konsep matematis siswa. *Pedagogy: Jurnal Pendidikan Matematika*, *11*(2), 1309–1334. https://doi.org/10.30605/3yn9k144

Aromataris, E., Lockwood, C., Porritt, K., Pilla, B., Jordan, Z., & editors. (2024). *JBI Manual for Evidence Synthesis*. https://doi.org/https://doi.org/10.46658/JBIMES-24-01

Budarsini, K. P., Suarsana, I. M., & Suparta, I. N. (2018). Model diskursus multi representasi dan kemampuan pemahaman konsep matematika siswa sekolah menegah pertama. *PYTHAGORAS Jurnal Matematika Dan Pendidikan Matematika*, *13*(2), 110–118. https://doi.org/10.21831/pg.v13i2.20047

Cahyani, N. I., Kurniawan, E., Arjudin, & Kurniati, N. (2025). Integrasi GeoGebra Dalam Pembelajaran Matematika Terhadap Pemahaman Konsep Matematis Siswa. *Griya Journal of Mathematics Education and Application*, *5*(2), 579–586. https://doi.org/10.29303/griya.v5i2.709

Cahyanti, A. D., Sutiarso, S., & Rosidin, U. (2023). Efektivitas E-LKPD Berbasis Web-Blogger Berbantuan FLIPHTML5 dan Quizizz untuk Meningkatkan Pemahaman Konsep Matematis. *EMTEKA: Jurnal Pendidikan Matematika*, *4*(2), 410–418. https://doi.org/10.24127/emteka.v4i2.3993

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Fadilah, A. N., Sutirna, S., & Haerudin, H. (2023). The effect of problem-based learning model assisted by Google Site on the students' mathematical concept understanding ability. *Union: Jurnal Ilmiah Pendidikan Matematika*, *11*(2), 184–190. https://doi.org/10.30738/union.v11i2.13273

Fauzi, A., Hardyanti, H., & Suryaningsih, S. (2026). Bridging the gap: How technology facilitates conceptual understanding in mathematics. *Indonesian Journal of Science and Mathematics Education*, *9*(1), 74–89. https://doi.org/10.24042/ijsme.v9i1.28655

Fitria, R., Imswatama, A., & Balkist, P. S. (2022). Analisis Kemampuan Pemahaman Konsep Matematis Siswa MTs Plus As-Sa'idah pada Materi Aljabar. *PRISMA*, *11*(2), 457–466. https://doi.org/10.35194/jp.v11i2.2451

Hutajulu, K. C., & Soesanto, R. H. (2023). Model discovery learning berbantuan geogebra sebagai upaya peningkatan pemahaman konsep matematika siswa. *Delta: Jurnal Ilmiah Dan Pendidikan Matematika*, *11*(1), 29–44. https://doi.org/http://dx.doi.org/10.31941/delta.v11i1.2475

Khotimah, K., Murtianto, Y. H., & Purwati, H. (2022). Profil Multipel Representasi Matematis Siswa SMP Ditinjau dari Multiple Intelligence dalam Memahami Konsep Bangun Ruang Sisi Datar dengan Teknologi Wolfram Alpha. *Imajiner: Jurnal Matematika dan Pendidikan Matematika*, *4*(4), 315–320. https://doi.org/10.26877/imajiner.v4i4.10185

Margareta, D., & Karimah, S. (2025). Developing Interactive Learning Media through Canva Website and Quizizz Mastery Peak Integration to Enhance Problem-Solving Skills. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *5*(3), 1358–1372. https://doi.org/10.51574/kognitif.v5i3.3655

Nay, F. A., & Maure, O. P. (2020). Kemampuan pemahaman konsep aljabar pada pembelajaran berbasis virtual manipulative. *Asimtot : Jurnal Kependidikan Matematika*, *2*(2), 177–192. https://doi.org/10.30822/asimtot.v2i2.775

Nurdin, E., Ma'aruf, A., Amir, Z., Risnawati, R., Noviarni, N., & Azmi, M. P. (2019). Pemanfaatan video pembelajaran berbasis Geogebra untuk meningkatkan kemampuan pemahaman konsep matematis siswa SMK. *Jurnal Riset Pendidikan Matematika*, *6*(1), 87–98. https://doi.org/10.21831/jrpm.v6i1.18421

Nurhairunnisah, N., & Sujarwo, S. (2018). Bahan ajar interaktif untuk meningkatkan pemahaman konsep Matematika pada siswa SMA kelas X. *Jurnal Inovasi Teknologi Pendidikan*, *5*(2), 192–203. https://doi.org/10.21831/jitp.v5i2.15320

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *PLOS Medicine*, *18*(3), e1003583. https://doi.org/10.1371/journal.pmed.1003583

Putri, A., & Pasandaran, R. F. (2024). Efektivitas penggunaan geogebra dalam meningkatkan pemahaman konsep siswa kelas xi sma negeri 10 luwu utara. *Pedagogy: Jurnal Pendidikan Matematika*, *9*(2), 494–507.

Ramadhani, W. P., & Mulbar, U. (2026). Analisis Representasi Visual Matematis Berbasis Etnomatematika Maluku Berbantuan Augmented Reality pada Materi Bangun Ruang Sisi Datar. *Jurnal Pendidikan Matematika Unpatti*, *7*(1), 30–40. https://doi.org/10.30598/jpmunpatti.v7.i1.p30-40

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Romadhani, D., & Harahap, N. A. (2022). Pengaruh Penggunaan Bahan Ajar Berbasis Website Terhadap Peningkatan Kemampuan Pemahaman Konsep Matematis Siswa. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *6*(2), 1222–1239. https://doi.org/10.31004/cendekia.v6i2.1340

Santosa, Y. T., Maulida, D. W., & Murtiyasa, B. (2025). Implementation of GeoGebra-based LMS canvas on conceptual understanding of geometry transformation of grade XI students. *AKSIOMA : Jurnal Matematika Dan Pendidikan Matematika*, *16*(1), 15–32. https://doi.org/10.26877/aks.v16i1.21713

Setiani, I., & Hendikawati, P. (2024). Kemampuan representasi matematis peserta didik pada pembelajaran Think Pair Share berbantuan media Canva. *Primatika : Jurnal Pendidikan Matematika*, *13*(2), 115–124. https://doi.org/10.30872/primatika.v13i2.4118

Silvina, N., Tumanggor, A. P., Tarigan, A. B., Lubis, D. M., Sibarani, M. A. T., & Siregar, B. H. (2025). Effect of Deep Learning Approach With GeoGebra-Based Interactive PowerPoint and Animated Videos on Concept Understanding. *Jurnal Pendidikan Matematika Universitas Lampung*, *13*(3), 157–171. https://doi.org/10.23960/mtk/v13i3.pp157-171

Siregar, N. F. (2021). Pemahaman Konsep Matematika Siswa SMP Melalui Pendekatan Realistic Mathematics Education. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *5*(2), 1919–1927. https://doi.org/10.31004/cendekia.v5i2.635

Suryawan, I. P. P., & Permana, D. (2020). Media Pembelajaran Online Berbasis Geogebra sebagai Upaya Meningkatkan Pemahaman Konsep Matematika. *PRISMA*, *9*(1), 108–117. https://doi.org/10.35194/jp.v9i1.929

Widiyanti, W., Sugiatno, S., & Mirza, A. (2021). Peningkatan pemahaman konseptual matematis dan respons siswa melalui pembelajaran berbasis multi representasi di sekolah menengah atas. *AL KHAWARIZMI: Jurnal Pendidikan Matematika*, *1*(2), 69–77. https://doi.org/10.46368/kjpm.v1i2.408

Yanti, R., Laswadi, L., Ningsih, F., Putra, A., & Ulandari, N. (2019). Penerapan pendekatan saintifik berbantuan geogebra dalam upaya meningkatkan pemahaman konsep matematis siswa. *AKSIOMA : Jurnal Matematika Dan Pendidikan Matematika*, *10*(2), 180–194. https://doi.org/10.26877/aks.v10i2.4399

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