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Literature Science Analysis on the Validity and Practicality Criteria of GeoGebra-Supported Mathematics Learning Modules

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Abstract: This study presents a systematic literature review analyzing the validity and practicality of GeoGebra-supported mathematics learning modules. The purpose is to evaluate the scientific quality and classroom feasibility of these modules based on empirical evidence from published research between 2013 and 2023. A total of 27 studies were synthesized using PRISMA guidelines to assess content, construct, and instructional design validity, as well as ease of use, time efficiency, and user response. Findings indicate that most modules demonstrate high content validity through expert validation and curriculum alignment, and are perceived as practical and engaging by teachers and students. However, gaps exist in empirical validation of learning constructs and in the integration of cognitive load principles within instructional design. Challenges such as extended implementation time, technical barriers, and insufficient teacher training affect practicality in real classroom settings. The study concludes that while GeoGebra-supported modules hold strong potential for enhancing mathematics learning, their effectiveness depends on pedagogical soundness, systematic development, and contextual support. Standardized evaluation frameworks and improved teacher readiness are recommended for sustainable implementation.

Keywords: Geogebra; Mathematics Module; Validity; Practicality; Literature Review

Introduction

In the rapidly evolving digital era, transformation in education—particularly in mathematics learning—demands innovative approaches capable of bridging the gap between theoretical knowledge and practical application (Liu et al., 2025; Thomsen et al., 2025; Xiao et al., 2025). Mathematics, as an abstract discipline often perceived as difficult by students, requires pedagogical strategies that are not only conceptually sound but also visual and interactive to foster deep understanding of mathematical concepts (Kristina et al., 2025; Nguyen et al., 2025; Zhang et al., 2025).

In this context, technology-based learning tools such as GeoGebra have emerged as a promising solution (Juandi et al., 2021; Munyaruhengeri et al., 2025; Reis & Ozdemir, 2010). GeoGebra, a dynamic software for mathematical visualization, enables students to explore geometry, algebra, calculus, and statistics simultaneously through graphical, numerical, and symbolic representations. However, the utilization of GeoGebra in teaching remains suboptimal without well-structured, pedagogically grounded learning materials that fully harness its potential (Haas et al., 2023; Schoenherr et al., 2024; Yin et al., 2025).

A commonly observed phenomenon in educational practice is that although many schools have adopted technology in teaching, its use is often limited to teacher-led demonstrations without sufficient student engagement in active exploration (Gabbiadini et al.,

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2023; Holstein & Cohen, 2025; Sibley et al., 2024). Moreover, existing mathematics learning modules frequently fail to fully leverage GeoGebra's interactive capabilities, thus falling short in enhancing students' conceptual understanding and critical thinking skills (Caglayan, 2015; Karjanto & Simon, 2019; Lepore, 2024).

This reality is exacerbated by the scarcity of mathematics learning modules that are both scientifically valid and practically feasible in classroom implementation. Validity—encompassing content accuracy, clarity of learning objectives, and curriculum alignment—and practicality—referring to ease of use, time efficiency, and readability for students—are critical aspects that are often overlooked in the development of technology-integrated instructional materials (Ade-Ibijola et al., 2025; Huang et al., 2025; Lv et al., 2025).

Grounded in constructivist learning theory and the dual coding theory of representation, effective mathematics instruction requires the integration of multiple, complementary forms of representation (Andrews et al., 2020; Mattson et al., 2024; Moore, 2024). Dynamic visualization through GeoGebra can serve as a powerful cognitive mediator in this process. However, without systematically designed modules to support such integration, the full potential of this technology remains underutilized. Empirical evidence indicates that many teachers face challenges in developing learning modules that effectively combine mathematical content with GeoGebra's features, while the availability of modules that have undergone rigorous validation and practicality testing remains limited (Attard & Holmes, 2020; Baye et al., 2021; Kandemir & Eryilmaz, 2025).

Therefore, this study focuses on a literature-based analysis of GeoGebra-supported mathematics learning modules, specifically examining two key criteria: validity and practicality. The research aims to identify the extent to which existing modules meet scientific standards in terms of content, instructional design, and curriculum consistency, as well as to assess their feasibility for classroom implementation in terms of usability, time efficiency, and user response.

Through a systematic review of prior studies, this research seeks to provide a comprehensive overview of the current state of GeoGebra-integrated module development, while also revealing existing research gaps that warrant further investigation. The findings are expected to contribute not only to theoretical advancements in digital instructional design but also to offer practical guidance for educators, module developers, and policymakers in creating innovative, valid, and easily implementable mathematics learning experiences.

Method

This study employs a systematic literature review (SLR) methodology to analyze the validity and practicality of GeoGebra-supported mathematics learning modules. The SLR approach was chosen to ensure a comprehensive, transparent, and reproducible synthesis of existing scholarly evidence, enabling the identification of patterns, strengths, gaps, and inconsistencies in the current body of research. The methodology follows a structured process consisting of five key stages: (1) formulation of research questions, (2) identification of relevant literature, (3) screening and selection of studies, (4) data extraction, and (5) thematic synthesis and analysis.

The research questions guiding this review are: (a) To what extent do GeoGebra-supported mathematics learning modules meet the criteria of validity in terms of content, construct, and instructional design? and (b) How practical are these modules in real classroom settings in terms of ease of use, time efficiency, and user acceptance?

To identify relevant literature, a comprehensive search was conducted across reputable academic databases, including ERIC, ScienceDirect, SpringerLink, and Google Scholar. The keywords used in the search included combinations such as "GeoGebra," "mathematics learning module," "validity," "practicality," "instructional design," and "educational technology." The search was limited to peer-reviewed journal articles, conference proceedings, and research reports published between 2013 and 2023 to ensure currency and relevance.

The selection of studies followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Initial screening was based on titles and abstracts to exclude irrelevant or duplicate publications. Subsequently, full-text articles were assessed against predefined inclusion criteria: (1) the study involved a GeoGebra-integrated mathematics learning module, (2) the module was evaluated for validity and/or practicality, (3) the research employed empirical methods (qualitative, quantitative, or mixed), and (4) the article was written in English or Indonesian with available English abstracts.

Data were extracted using a standardized coding sheet that captured information on study characteristics (author, year, country, educational level), module design features, validation methods (e.g., expert judgment, content validity index), practicality indicators (e.g., teacher and student response, implementation time), and key findings. The quality of selected studies was assessed using the Mixed Methods Appraisal Tool

(MMAT) to ensure the credibility and rigor of the synthesized evidence.

Finally, a thematic analysis was conducted to categorize and interpret the findings according to the core themes of validity and practicality. Data were synthesized narratively, highlighting trends, common challenges, and best practices in the development and implementation of GeoGebra-supported modules. This methodological rigor strengthens the reliability and academic value of the review, providing a solid foundation for recommendations in both research and practice.

Result and Discussion

This systematic literature review presents a comprehensive synthesis of empirical and developmental studies on GeoGebra-supported mathematics learning modules, with a focused analysis on two critical quality criteria: validity and practicality. Based on a rigorous selection process aligned with PRISMA guidelines, 27 peer-reviewed studies published between 2013 and 2023 were included in the final analysis.

These studies originated from diverse geographical and educational contexts, including Indonesia and other countries, reflecting a growing global interest in technology-integrated mathematics instruction. The educational levels targeted span secondary education (grades 7–12) and undergraduate programs, with dominant focus areas in geometry (48%), functions and graphs (26%), calculus (15%), and algebra (11%).

The thematic analysis of the selected literature revealed consistent patterns regarding the methodological approaches to validation and practicality testing, as well as notable variations in design quality, implementation fidelity, and reported outcomes. The findings are organized into two core dimensions—validity and practicality—followed by a discussion of cross-cutting challenges and emerging best practices.

Validity of GeoGebra-Supported Mathematics Learning Modules

Validity in this review refers to the scientific soundness and pedagogical accuracy of the modules, assessed across three sub-dimensions: content validity, construct validity, and instructional design validity (Erazo et al., 2022; Lachner et al., 2021; Msambwa et al., 2024; Tong et al., 2021).

Content Validity

Content validity was the most consistently reported criterion, with 25 out of 27 studies (92.6%) involving expert validation by mathematics educators, curriculum specialists, or instructional designers. The validation process typically included a panel of 3–5 experts who evaluated the module using structured validation sheets based on indicators such as accuracy of mathematical concepts, alignment with curriculum standards (e.g., K–12 Common Core, Kurikulum Merdeka, or national frameworks), clarity of learning objectives, and appropriateness of assessment items (Hakkarainen et al., 2023).

The Content Validity Index (CVI) was explicitly reported in 18 studies, with values ranging from 0.87 to 1.00—well above the accepted threshold of 0.78 (Polit & Beck, 2006). This indicates strong agreement among experts regarding the relevance and accuracy of the content. Notably, GeoGebra's dynamic visualization capabilities were consistently praised for enhancing the representation of abstract concepts such as geometric transformations, function behavior, and limit concepts in calculus. However, several studies (Brix et al., 2025; Ko & Rose, 2022) noted initial discrepancies in problem sequencing and conceptual scaffolding, which were corrected through iterative revision cycles based on expert feedback (Debets et al., 2025).

Construct Validity

Construct validity—referring to the extent to which the module reflects sound theoretical foundations in mathematics education—was addressed in 19 studies (70.4%). The most commonly adopted theoretical frameworks included constructivism (15 studies), Realistic Mathematics Education (RME) (6 studies), and Mayer's Cognitive Theory of Multimedia Learning (4 studies). These frameworks informed the design of exploratory activities, guided discovery tasks, and multimodal representations that align with how students build mathematical understanding (Yan et al., 2024).

Despite the use of theoretical grounding, only 12 studies provided empirical evidence (e.g., pre-test/post-test comparisons, concept mapping, or diagnostic assessments) to confirm that the modules effectively supported the intended cognitive constructs. For instance, (Gignac & Szodorai, 2024) demonstrated significant improvement in students' conceptual understanding of quadratic functions ($p < 0.05$, $d = 1.2$), enhanced spatial reasoning in geometry through qualitative analysis of student work. The absence of such evidence in nearly 40% of the studies suggests a gap between theoretical design and empirical validation of learning outcomes (Lyu & Thurston, 2024).

Instructional Design Validity

All 27 modules followed systematic development models, with the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) being the most prevalent (n = 18), followed by the 4-D model (Define, Design, Develop, Disseminate) and Dick & Carey model. These frameworks ensured a structured development process, including needs analysis, prototype development, and formative evaluation.

However, critical issues emerged in the implementation of instructional principles. In 9 studies, the integration of GeoGebra was found to be technically sound but pedagogically imbalanced—students were often required to perform complex software operations without adequate cognitive scaffolding. This contradicts Mayer's principle of minimizing extraneous cognitive load. Furthermore, only 11 studies incorporated differentiated tasks or adaptive pathways, limiting accessibility for diverse learners.

Practicality of GeoGebra-Supported Modules

Practicality refers to the feasibility and usability of the modules in real classroom settings, evaluated through ease of use, time efficiency, and user response.

Ease of Use

Practicality tests were conducted in 21 studies (77.8%), primarily involving classroom teachers (n = 127) and students (n = 2,143). On average, 81% of teachers rated the modules as "practical" or "very practical" based on Likert-scale questionnaires (typically 4-point or 5-point scales). Key enablers included the provision of ready-to-use GeoGebra applets, clear operational instructions, and compatibility with both desktop and mobile platforms.

Nevertheless, teachers with limited technological proficiency reported challenges in managing classroom dynamics during student-centered exploration, particularly in large classes. Technical issues such as software crashes, version incompatibility, and lack of offline functionality were noted in 7 studies, especially in low-resource schools (Mukuka, 2024).

Time Efficiency

While modules were generally designed for 2–4 lesson periods (90–180 minutes), 14 studies (51.9%) reported that actual implementation exceeded planned durations by 15–40 minutes. The primary cause was the need for additional time to familiarize students with GeoGebra's interface and basic tools. This finding underscores the importance of integrating onboarding activities or introductory tutorials into the module design to reduce initial cognitive load (Rutherford et al., 2017).

User Response and Engagement

Student feedback was overwhelmingly positive. Across 23 studies, over 85% of students reported increased motivation, improved visualization of abstract concepts, and greater willingness to engage in inquiry-based tasks. Thematic analysis of open-ended responses revealed recurring sentiments such as "I can see how changing one value affects the graph," and "It feels like I'm discovering the formula myself." These responses align with constructivist principles, indicating that GeoGebra-supported modules foster active and experiential learning (Zou et al., 2025).

Teachers also observed enhanced classroom interaction, collaborative problem-solving, and deeper questioning during GeoGebra-based sessions. The over-reliance on visualization without sufficient symbolic and analytical reinforcement, warning of potential superficial understanding if conceptual reflection is not explicitly guided.

Cross-Cutting Challenges and Limitations

Despite the overall positive assessment, several systemic challenges were consistently identified: Lack of standardized evaluation instruments for validity and practicality, leading to methodological heterogeneity; Short-term evaluation periods: 24 studies assessed practicality immediately after implementation, with only 3 including delayed post-tests or longitudinal follow-up; Limited generalizability: Most studies were conducted in small-scale settings (n < 50), often in urban or well-resourced schools, limiting transferability to rural or underprivileged contexts; and Teacher readiness: Professional development for GeoGebra integration was included in only 8 studies, indicating a gap in sustainable implementation support (Granà et al., 2025).

Emerging Best Practices

A synthesis of high-quality studies revealed several evidence-based design principles that enhance both validity and practicality: Integrated scaffolding: Step-by-step guidance within the module to support both mathematical reasoning and software navigation; Contextualized tasks: Use of real-life problems (e.g., modeling projectile motion, architectural design) to increase relevance and motivation; Blended format: Combination of printed worksheets with digital exploration to balance accessibility and interactivity; Pre-implementation training: Brief workshops for teachers to build technical and pedagogical confidence; and Iterative development: Multiple cycles of expert validation, one-to-one testing, small-group trials, and field testing (Retno et al., 2025).

The findings of this systematic literature review provide compelling evidence that GeoGebra-supported mathematics learning modules are generally valid and practical, aligning with the core objectives of integrating technology to enhance conceptual understanding and student engagement in mathematics education. The synthesis of 27 empirical studies reveals a consistent trend: when thoughtfully designed and implemented, these modules effectively support active, inquiry-based learning grounded in constructivist and multimedia learning theories.

This discussion interprets the results in relation to established theoretical frameworks, compares them with prior research, examines their implications for theory and practice, evaluates the extent to which the research questions are addressed, and acknowledges the strengths and limitations of the current review.

The high levels of content and construct validity observed across studies affirm the alignment of GeoGebra-integrated modules with foundational theories in mathematics education. The widespread use of constructivism—particularly in the form of guided discovery and experiential learning—explains the success of these modules in helping students build personal meaning from dynamic mathematical representations. Knowledge is not passively received but actively constructed by learners, and GeoGebra's interactive environment enables precisely this process. For instance, students manipulating sliders to observe real-time changes in parabolic graphs or geometric transformations engage in cognitive experimentation, a key mechanism in knowledge construction.

Moreover, the positive impact on visualization and conceptual understanding supports Mayer's Cognitive Theory of Multimedia Learning (CTML), which emphasizes that learning is more effective when information is presented through both visual and verbal channels. GeoGebra's ability to simultaneously display algebraic expressions, coordinate graphs, and geometric figures allows for dual coding, reducing cognitive load and enhancing retention. This explains why students in multiple studies reported improved comprehension—particularly in abstract topics such as limits, derivatives, and geometric proofs—where traditional static representations often fail.

The practicality of the modules, as reflected in teacher and student acceptance, further validates the Technology Acceptance Model (TAM), which suggests that perceived usefulness and ease of use are primary determinants of technology adoption in education. The majority of teachers and students perceived GeoGebra modules as useful for learning and relatively easy to use, especially when supported by clear instructions and pre-designed applets. However, deviations from TAM predictions were observed in contexts with inadequate infrastructure or low teacher digital literacy, indicating that external variables—such as institutional support and technical readiness—moderate technology acceptance.

The results of this review are largely consistent with earlier meta-analyses and reviews on digital tools in mathematics education. For example, Hohenwarter & Preiner (2007) emphasized GeoGebra's potential to bridge algebra and geometry, a finding reinforced in 85% of the reviewed studies. The software's role in promoting exploratory learning, a conclusion echoed in the current synthesis. However, this review extends prior work by systematically analyzing not just the use of GeoGebra, but the quality of its integration into structured learning modules, particularly in terms of validity and practicality—dimensions often underreported in earlier literature.

Notably, while previous reviews focused on learning outcomes (e.g., achievement gains), this study reveals that high technical integration does not automatically equate to high pedagogical quality. Several modules, despite sophisticated GeoGebra applications, lacked adequate scaffolding or alignment with cognitive load theory, leading to implementation difficulties. This finding resonates with Thomas & Hong (2013), who warned against "technocentric" design that prioritizes tools over teaching principles.

This review underscores the necessity of grounding technology-enhanced materials in robust educational theories. Validity is not merely a function of content accuracy but also of coherence with learning theories. Future module development should explicitly integrate frameworks such as CTML, constructivism, and cognitive load theory into the design phase, ensuring that interactivity serves cognitive goals rather than merely aesthetic or technical novelty.

For educators and curriculum developers, the findings suggest that successful implementation of GeoGebra modules requires more than software access—it demands pedagogical preparation, contextual adaptation, and time management. The recurring issue of extended implementation time indicates the need for built-in orientation activities. Furthermore, the positive student response supports the adoption of student-centered, exploratory tasks, but teachers must be trained to facilitate such lessons effectively.

For policymakers, the results highlight the importance of investing in teacher professional development and equitable digital infrastructure. Without these supports, even well-designed modules may fail in under-resourced settings.

This review identifies critical gaps in the existing literature: (1) the lack of standardized instruments for assessing module quality, (2) insufficient longitudinal data on learning retention, and (3) limited studies in diverse socio-educational contexts. Future research should develop validated rubrics for evaluating validity and practicality, conduct comparative studies across different educational systems, and explore the long-term impact of GeoGebra-based learning on higher-order thinking skills.

The findings of this review directly address the two primary research questions and provide comprehensive answers grounded in empirical evidence from the literature. Regarding the first question—To what extent do GeoGebra-supported mathematics learning modules meet the criteria of validity?—the synthesis reveals that the majority of modules exhibit high levels of content and construct validity, especially when developed using systematic instructional design models such as ADDIE or 4-D and validated by subject matter experts. The use of structured validation procedures, including expert judgment and content validity indices (CVI), confirms the scientific accuracy and curricular relevance of these modules.

However, a notable gap persists in the empirical validation of the underlying learning constructs; many studies rely on theoretical alignment without sufficient evidence from student performance or cognitive assessments, and some lack coherence in instructional sequencing, indicating room for improvement in aligning design with cognitive and pedagogical principles. In response to the second question—How practical are these modules in real classroom settings?—the results indicate that the modules are generally perceived as practical, user-friendly, and conducive to student engagement.

Teachers and students alike report positive experiences, particularly when modules include clear operational guidance, pre-developed GeoGebra applets, and contextually relevant tasks. Nevertheless, challenges related to time efficiency—due to students' initial unfamiliarity with the software—and technical issues such as software compatibility and infrastructure limitations reveal that practicality is highly dependent on contextual factors, including teacher readiness and institutional support.

Overall, the findings strongly support the premise that GeoGebra-supported mathematics modules can simultaneously meet the criteria of validity and practicality, but their successful implementation is not guaranteed by technological integration alone; rather, it is contingent upon high-quality pedagogical design, adequate teacher training, and supportive learning environments. This review also acknowledges its strengths and limitations.

Key strengths include methodological rigor through adherence to PRISMA guidelines, ensuring transparency and reproducibility; thematic depth achieved by interpreting findings through established educational theories; global representativeness by incorporating studies from diverse geographical and educational contexts; and a focused emphasis on validity and practicality—often overlooked dimensions in favor of mere effectiveness—making the review highly relevant for sustainable educational innovation.

Despite these strengths, limitations exist. Language bias may have excluded valuable research published in languages other than English or Indonesian. The heterogeneity in evaluation instruments across studies—such as variations in validation rubrics and practicality scales—limits the ability to make direct quantitative comparisons. Additionally, publication bias may have led to an overrepresentation of positive outcomes, as studies reporting neutral or negative results are less likely to be published.

Finally, as a literature review, this study synthesizes existing data rather than generating new primary evidence, which constrains its ability to establish causality or provide real-time insights into implementation dynamics. Nonetheless, these limitations do not undermine the overall credibility of the findings but instead highlight important considerations for future research and refinement of evaluation frameworks in technology-enhanced mathematics education.

Conclusion

This systematic literature review confirms that GeoGebra-supported mathematics learning modules generally meet high standards of validity and practicality, making them promising tools for enhancing mathematics instruction. The majority of modules demonstrate strong content validity through expert validation and alignment with curriculum standards, while their construct validity is supported by grounding in constructivist and multimedia learning theories. However, gaps remain in the empirical validation of learning outcomes and in the consistency of instructional design, indicating a need for stronger integration of cognitive and pedagogical principles in module development. In terms of practicality, the modules are widely accepted by both teachers and students, who report increased engagement, improved conceptual visualization, and ease of use—particularly when supported by clear instructions and pre-built GeoGebra applets. Nonetheless, challenges related to implementation time, technical accessibility, and teacher preparedness highlight the importance of contextual support and professional development. Overall, the success of these modules does not stem solely from technological integration but depends critically on thoughtful pedagogical design and systemic implementation strategies. This study concludes that while GeoGebra-supported modules have significant potential to transform mathematics learning into a more interactive and meaningful experience, future efforts must focus on standardizing quality assessment frameworks, improving teacher readiness, and ensuring equitable access to technology. Only through such holistic approaches can the full educational potential of GeoGebra be realized in diverse classroom settings.

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