Integrating Geometer's Sketchpad and Realistic Mathematics Education: A Visual Media Model for Plane Geometry

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Abstrak

Permasalahan rendahnya pemahaman mahasiswa terhadap materi geometri bangun datar akibat media pembelajaran yang kurang interaktif dan kontekstual menjadi fokus penelitian ini. Untuk mengatasi hal tersebut, penelitian ini berupaya mengintegrasikan Geometer's Sketchpad (GSP) dengan pendekatan Realistic Mathematics Education (RME) menjadi sebuah media visual interaktif. Penelitian ini bertujuan menilai kualitas media dari aspek validitas, kepraktisan, dan efektivitas. Proses pengembangan mengikuti model ADDIE, melibatkan 32 mahasiswa pendidikan matematika yang mengikuti perkuliahan geometri di Universitas Siliwangi. Instrumen penelitian menggunakan lembar penilaian ahli, angket kepraktisan, dan tes penguasaan konsep. Analisis data menunjukkan media telah tervalidasi (87,75%), dinilai praktis (86,5%), dan mampu meningkatkan hasil belajar mahasiswa (N-Gain 0,53). Media ini terbukti layak dan efektif dalam memperkuat pemahaman geometri bangun datar pada mahasiswa.
***Kata Kunci**: media visual interaktif; Geometer's Sketchpad; Realistic Mathematics Education; geometri bangun datar; pemahaman geometri.*

Abstract

The low level of students' understanding of plane geometry material, attributed to the lack of interactive and contextual learning media, has become the focus of this research. To address this issue, the study aims to integrate Geometer's Sketchpad (GSP) with the Realistic Mathematics Education (RME) approach to develop an interactive visual media. The objective of this research is to evaluate the quality of the media in terms of validity, practicality, and effectiveness. The development process follows the ADDIE model and involves 32 mathematics education students enrolled in geometry courses at Siliwangi University. The research instruments include expert validation sheets, practicality questionnaires, and concept mastery tests. Data analysis indicates that the media has been validated with a score of 87.75%, rated as practical at 86.5%, and demonstrated the ability to improve students' learning outcomes, with a normalized gain (N-Gain) of 0.53. The media is proven to be feasible and effective in enhancing students' understanding of plane geometry.
Keywords: interactive visual media; Geometer's Sketchpad; Realistic Mathematics Education; plane geometry; plane geometry understanding.

I. INTRODUCTION

The digital transformation occurring in the modern era has profoundly impacted the educational landscape, including mathematics instruction. A persistent challenge remains the inadequate conceptual understanding of plane geometry among university students. This issue primarily stems from the dominance of conventional instructional approaches that lack visual engagement and interactivity, thereby hindering students' exploration and reasoning regarding abstract geometric objects (Ikhsan, Rochaminah, & Mastura, 2024; Xu, 2025). Consequently, the utilization of educational technology, particularly dynamic geometry software (DGS), has emerged as a solution continuously being developed to enhance the quality and effectiveness of mathematics learning.

Geometer's Sketchpad (GSP) has emerged as a software tool offering visualization and direct interaction with geometric objects. GSP not only assists in dynamically visualizing plane figures but also encourages students to engage in independent exploration, thereby strengthening deep conceptual understanding. The transition from traditional teaching methods to the utilization of technology-based visual media such as GSP is believed to enhance student motivation, interest, and engagement in the learning process, particularly when dealing with abstract subject matter (Ikhsan et al., 2024; Xu, 2025).

Beyond visualization, the success of mathematics instruction is heavily influenced by the relevance of the material to real life. The Realistic Mathematics Education (RME) approach has proven effective by positioning contextual experiences as the foundation for constructing mathematical understanding (Afriansyah & Turmudi, 2022; Setia & Sandy, 2024; Sarumaha, Khairiani, & Amirah, 2025). Through activities and problems relevant to daily life, RME facilitates students in constructing mathematical meaning in a gradual and contextual manner (Aklimawati, Listiana, Isfayani, Zainuddin, & Aulia, 2022; Putri & Syafdaningsih, 2024; Olivia et al., 2024). By integrating GSP and RME, it is anticipated that the resulting learning media will not only be visually appealing but also capable of conveying deep understanding regarding both concepts and their application in real-world situations.

Numerous studies have demonstrated the effectiveness of geometry-based visual tools, including software such as GeoGebra, Cabri 3D, and Desmos, in improving students' spatial abilities, mathematical literacy, and conceptual understanding (Astuti, Armanto, & Hasratuddin, 2024; Makmur, Ernawati, Nirfayanti, & Suryaningsih, 2025; Ramidha, Shodikin, & Abdullah, 2025; Setiawati, Risalah, & Oktaviana, 2021). GeoGebra has been widely utilized in teaching various geometric concepts and has proven to be effective and user-friendly (Monalisa, Nurusliah, & Oktafia, 2023; Setiawati et al., 2021; Setyawan & Wijaya, 2023; Wijaya, Rosyada, & Hardianto, 2023). Nevertheless, research specifically exploring the development of visual media using Geometer's Sketchpad grounded in the RME approach for plane geometry remains

relatively scarce (Hadi & Mulyadin, 2022; Ikhsan et al., 2024). Furthermore, comprehensive studies regarding the validity and utility of the media resulting from such integration within direct classroom learning contexts are limited.

The gap in this field of research stems from the lack of systematic exploration regarding the integration of GSP and RME in developing interactive visual media for plane geometry instruction. Many prior studies have predominantly focused on the use of a single software tool or a single pedagogical approach in isolation, leaving their collaborative potential not fully optimized. Comprehensive evaluations of the validity and practicality of the integrated media are also infrequently conducted, despite the critical importance of these aspects in ensuring the media can be implemented effectively in mathematics learning (Ikhsan et al., 2024; Kadarisma, Priatna, & Dahlan, 2022; Xu, 2025).

Addressing this identified gap, the present study aims to develop interactive visual media resulting from the integration of GSP and RME principles on plane geometry material. The primary focus of this research extends beyond technological innovation to include a systematic examination of the media's validity and practicality. Thus, the findings of this study are expected to offer theoretical and practical benefits while simultaneously enriching the literature related to innovations in mathematics learning media in Indonesia.

The central research question addressed in this study is: What are the levels of validity and practicality of the interactive visual media resulting from the integration of GSP and the RME approach on plane geometry material? To answer this inquiry, the study involves creating interactive visual media by leveraging the interactive features of GSP, followed by validation and practicality testing involving mathematics education experts and practitioners. Validity will be analyzed across several aspects, while practicality will be assessed through user ease of use.

Prior research on the development of geometry learning media (based on GeoGebra, Cabri 3D, Desmos, or other interactive multimedia) has demonstrated positive impacts on improving learning outcomes, geometric representation abilities, and student motivation (Astuti et al., 2024; Makmur et al., 2025; Pasaribu & Ramalisa, 2020; Putrie, 'Adna, & Rahmawati, 2023; Ramidha et al., 2025; Setiawati et al., 2021; Jamil, Sa'dijah, & Susanto, 2022; Kurniawan et al., 2024; Pujiani et al., 2025; Sulthoni & Handayani, 2025). However, the integration of technological visualization power with the relevance of real-life contexts for university students, as emphasized in RME, remains underexplored, particularly regarding the utilization of GSP for plane geometry. This study is expected to address this challenge and provide innovative solutions for the development of mathematics learning media.

Theoretically, this study adopts the foundation of RME, which connects material with students' real experiences (Aklimawati et al., 2022; Putri & Syafdaningsih, 2024; Hamid & Afriansyah, 2024), alongside the application of dynamic

geometry software in designing visual media (Hadi & Mulyadin, 2022; Ikhsan et al., 2024). By synthesizing these two theoretical frameworks, this study aims to create learning media that is conceptually effective, visually innovative, and capable of constructing students' mathematical reasoning. Furthermore, this study aligns with recent findings regarding the importance of attending to the validity and practicality levels of mathematics learning media usage (Kadarisma et al., 2022; Xu, 2025; Zain, Marhayati, & Abdussakir, 2024).

Specifically, this study aims to develop interactive visual media for plane geometry resulting from the integration of GSP and the RME approach, while simultaneously evaluating the validity and practicality of the media product within higher education. The expected outcome is the creation of learning media that facilitates visual exploration, reinforces conceptual understanding, and enhances student motivation. This research is also projected to provide practical recommendations for the use of interactive visual media for mathematics instructors, tailored to the needs of students in the digital era. The researchers hypothesize that the interactive visual media for plane geometry resulting from the GSP and RME integration possesses high levels of validity and practicality, thereby being well-accepted by users as an innovative learning tool. If substantiated, these findings could reinforce the theoretical underpinnings of mathematics learning media development. Additionally, they may offer practical benefits by increasing learning interactivity in geometry, extending the media model to other topics or educational levels, and

affirming the role of GSP combined with RME as an innovator in 21st-century mathematics education.

II. METHOD

This study employed a Research and Development (R&D) approach utilizing the ADDIE model, which comprises five phases: Analysis, Design, Development, Implementation, and Evaluation. The research process commenced with a needs analysis conducted through observations and discussions with the geometry course lecturer, followed by the design, development, and implementation of interactive visual media resulting from the integration of Geometer's Sketchpad (GSP) and the Realistic Mathematics Education (RME) approach. The researcher was actively engaged throughout all phases, ranging from needs mapping and media prototype development to the execution of trials and the evaluation of results at each stage.

The study involved 32 undergraduate students enrolled in the geometry course as research subjects. The participants were selected using a purposive sampling technique based on specific criteria: possessing adequate basic computer operation skills, having no prior familiarity with GSP, and confirming their availability to participate in the entire research series. Furthermore, the study involved lecturers to assess practicality, a subject matter expert as a content validator, and a media expert as a visual design validator.

The research instruments employed included: (1) validation sheets to assess material substance, visual display, and the alignment between the visual media and

the GSP-RME integration; (2) a four-point Likert scale practicality questionnaire administered to lecturers and students to measure ease of use, attractiveness, and the utility of the media; (3) a structured interview guide to explore user perceptions, experiences, and suggestions; and (4) a conceptual understanding test aligned with the learning indicators for plane geometry. Data collection was conducted comprehensively through direct observation during the learning process, questionnaire administration, structured interviews, and documentation of student learning outcomes in each media trial cycle.

The primary hardware utilized in this study consisted of computers installed with Geometer's Sketchpad software version 5.06. Additionally, the research utilized a digital version of the GSP module, Student Worksheets (*Lembar Kerja Mahasiswa* or LKM), and a set of learning outcome tests specifically developed to evaluate media effectiveness. The research was conducted over a four-month period, from January to April 2024, at the computer laboratory of the Faculty of Teacher Training and Education (FKIP), Universitas Siliwangi. During the implementation, the researcher was physically present at every stage to guide and monitor the learning process and participant interactions.

Quantitative data analysis was performed descriptively using SPSS by calculating the mean percentage of validation scores, practicality scores, and student learning outcome scores (including improvement analysis via the N-Gain test). Meanwhile, qualitative data were analyzed thematically through a process of coding data derived from observations, interviews, and documents related to participant experiences. Triangulation was conducted across data sources (lecturers, students, experts), data collection techniques (observation, questionnaires, interviews), and through member checking with key informants. All research procedures adhered to research ethics principles, including obtaining permission from relevant institutions and maintaining the confidentiality of data and the identities of all participants. This systematic and transparent approach is intended to facilitate the replication of similar studies in the future.

III. RESULT AND DISCUSSION

This research was conducted within the Mathematics Education Study Program at Universitas Siliwangi, involving 32 students as research subjects. The study focused on the development and implementation of interactive visual media resulting from the integration of Geometer's Sketchpad (GSP) and the Realistic Mathematics Education (RME) approach for teaching plane geometry. The research informants consisted of the course lecturer (DR), two teaching assistants (RS and LK), and several students, specifically IM, DT, MA, and AR.

A. Research Result

Preliminary findings obtained through observations and interviews indicated that the majority of students (72%) experienced difficulties in understanding plane geometry concepts, particularly in visualizing transformations and symmetry. The conventional instructional media

previously employed offered limited support for interaction and independent exploration. This was corroborated by DR's statement: *"Students often misidentify reflectional and rotational symmetry and struggle to predict transformation outcomes when relying solely on two-dimensional static images."*

The developed GSP-based media enables students to construct and manipulate various shapes, including triangles, squares, rectangles, trapezoids, kites, and circles. The media incorporates four essential features: (1) The ability to directly manipulate objects through translation, reflection, rotation, and dilation; (2) Visualization of centers of rotation and lines of symmetry; (3) Integration of exploratory tasks aligned with the RME approach based on contextual problems; and (4) GSP activities designed to facilitate the completion of Student Worksheets (*Lembar Kegiatan Mahasiswa* or LKM).

The media was validated by experts in RME, instructional media, and learning evaluation, all of whom assessed the visualization, content, interactivity, and application of RME principles. The media validation results are presented in Table 1.

Table 1.
Visual Media Validation Results

Aspect	Score (%)	Category
Content	89	Very Valid
Visualization	87	Very Valid
Interactivity	85	Valid
RME Principles	90	Very Valid

Based on Table 1, the validation score averaged 87.75%, indicating that the media product is eligible for implementation in learning. The experts provided specific feedback, such as: *"The animation features significantly assist students in understanding transformations"* (RS) and *"The LKM activities are aligned with RME syntax"* (LK).

The media trial was conducted on a limited scale within one class, where students utilized the learning media both individually and in groups, supported by LKM designed around contextual problems. The measurement of student understanding before (pretest) and after (posttest) the implementation of the media is presented in Table 2.

Table 2.
Comprehension Test Results

Stage	Average Score
Pretest	54,2
Posttest	78,4
N-Gain	0,53

Table 2 illustrates an increase in the average score from pretest to posttest by 24.2 points, demonstrating a significant improvement in student understanding. Statistical analysis using a t-test yielded a p-value < 0.05, confirming that this improvement is statistically significant. These results highlight a marked increase in scores following the use of interactive GSP media, illustrating an enhanced understanding of plane geometry concepts.

The practicality aspect of the media was measured using a questionnaire, with the summary of results presented in Table 3.

Table 3.
Practicality Response Results

Indicator	Score (%)
Ease of Use	88
Display Clarity	86
Context Suitability	85
Learning Benefits	87
Average	86,5

The average practicality score of 86.5% indicates that the media is considered highly user-friendly and beneficial in the learning process. Students provided positive feedback, including: *"I understand rotational symmetry better after practicing it on Sketchpad"* (IM), and *"Real-context tasks make the material easier to comprehend"* (MA). During implementation, students appeared increasingly active in discussions, exploring features, and testing new ideas.

Several refinements were made following the trial, including: (1) The addition of video tutorials for GSP usage; (2) The inclusion of contextual problem illustrations related to batik patterns and city parks; (3) The embedding of automatic labels on each shape; and (4) The restructuring of the LKM to be more systematic and reflective.

The media was subsequently implemented over three main meetings, resulting in an average posttest score increase of 24.2 points. Furthermore, 88% of students reported that classroom dynamics became more active and exploratory, and they felt assisted in understanding abstract concepts.

Based on the findings above, the interactive visual media resulting from the integration of GSP and RME has proven to be highly valid, practical, and effective in enhancing the understanding of plane geometry concepts. This media is recommended as a breakthrough innovation for geometry instruction in higher education.

B. Discussion

This study addresses critical issues regarding the effectiveness of interactive visual media resulting from the integration of GSP and the RME approach in plane geometry instruction at the higher education level. Through a systematic research process, robust evidence was obtained demonstrating that the developed media achieved a very high level of validity from experts and received highly positive practicality responses from both students and lecturers. Consequently, it is confirmed that this media meets feasibility standards and can be widely adopted in the plane geometry learning process.

Specifically, the research findings answer the two main research problems. First, regarding validity, assessments from subject matter experts, media experts, and educational practitioners confirmed that the interactive visual media integrating GSP and RME met the "very valid" criteria. Second, regarding practicality, feedback from students and lecturers involved in the trials consistently stated that the media was user-friendly, engaging, and capable of enhancing learning effectiveness. Thus, both research questions have been explicitly answered through strong empirical data.

The findings were obtained through a phased process, beginning with media development that optimized GSP's dynamic features to visualize plane geometry concepts interactively. Simultaneously, the RME approach was integrated to ensure that the materials and activities presented were rooted in real-life contexts relevant to students. Comprehensive validation involved various experts evaluating aspects

of substance, language, presentation, and graphic display. Practicality testing subsequently involved students and lecturers utilizing the media in limited learning settings, providing a holistic view of the media's utility and acceptability.

The interpretation of these findings suggests that the integration of GSP and RME is capable of providing a deeper and more meaningful learning experience for students. The resulting media allows students to directly manipulate geometric objects, explore the properties of plane figures, and connect abstract concepts contextually. These findings align with the RME approach, which emphasizes knowledge construction through meaningful activities and realistic context-based mathematics learning (Aklimawati et al., 2022; Putrie et al., 2023).

These findings also corroborate the results of Ikhsan et al. (2024) and Hadi & Mulyadin (2022), which affirm the effectiveness of GSP in enhancing the understanding and visualization of geometric concepts. Students utilizing GSP's interactive features demonstrated significant improvements in spatial abilities and mathematical reasoning. Furthermore, this visual media model aligns with constructivist theory, which views learning as an active process where students construct their own knowledge through exploration, discussion, and reflection on their learning experiences.

This research supports previous findings regarding the utilization of interactive learning media in dynamic geometry, which has proven effective in strengthening mathematical skills and student understanding (Monalisa et al., 2023;

Setiawati et al., 2021; Xu, 2025). The findings also support Ikhsan et al. (2024) and Hadi & Mulyadin (2022), who reported that GSP activities in geometry learning positively impact learning outcomes, particularly in spatial reasoning and concept visualization.

The integration of the RME approach in this media remains consistent with the findings of Aklimawati et al. (2022), Putrie et al. (2023), and Lubis, Siregar, & Syahlan (2022), which emphasize the importance of realistic contexts in facilitating students' knowledge transfer. The integration of GSP and RME in visual media also supports the results of Nguyễn & Từ (2024), who found that Sketchpad can expand opportunities for students' independent exploration in understanding geometric concepts more deeply.

This study enriches the body of research on technology-based interactive learning media development, including those based on GeoGebra (Ramidha et al., 2025; Setyawan & Wijaya, 2023), Desmos (Astuti et al., 2024), and other interactive multimedia (Azzahro, Mawarsari, & Aziz, 2025a, 2025b; Pasaribu & Ramalisa, 2020). The results reinforce that the combination of contextual elements, high-quality visualization, and interactivity in learning media serves as a key factor in improving the quality of the mathematics learning process.

Theoretically, the RME premise that meaningful mathematics learning must stimulate active student exploration and originate from realistic situations (Aklimawati et al., 2022) has been confirmed by this study. Aligning with these findings, the research also reaffirms

constructivist theory, which posits that optimal mathematics learning occurs when students actively construct knowledge through object manipulation and reflection on learning experiences (Lubis et al., 2022; Putrie et al., 2023).

On the other hand, this research enriches the classical RME approach by modifying it through the addition of a digital visualization dimension adaptive to 21st-century learning needs via GSP integration. The proposed theoretical model, GSP-based plane geometry visual media integrated with the RME approach, has proven to be valid, practical, and relevant for application in higher education mathematics contexts.

The findings also challenge the conventional view that limits geometry learning media to concrete props or static visuals, as critiqued by Monalisa et al. (2023) and Wijaya et al. (2023). By leveraging GSP's interactive features, this media successfully overcomes the limitations of conventional media and expands opportunities for students to experience geometry learning dynamically, exploratively, and meaningfully.

The implication of these findings is a tangible contribution to the development of mathematics learning media theory by integrating the RME approach with interactive digital tools. This study recommends the importance of developing mathematics learning media that combine realistic contexts, interactive visualization, and accessibility for students and lecturers. This is intended to serve as a strategy for improving the quality of mathematics education in the future.

In terms of implementation, this media model holds significant potential for adaptation to other geometry topics and application across various educational levels to strengthen mathematics learning quality in the digital era. Consequently, the results of this study are expected to serve as a foundation for sustainable innovation in the development of contextual technology-based learning media.

In conclusion, the results explicitly confirm that interactive visual media for plane geometry resulting from the integration of GSP and the RME approach is proven to be highly valid and practical for use in geometry instruction. Beyond its effectiveness, the integration of digital technology and the RME approach within a single medium is highly relevant to contemporary educational demands. This study simultaneously illustrates a theoretical modification in the form of interactive visual media integrating GSP and RME as a strategic innovation in higher education geometry learning, thereby reinforcing RME and constructivist theories.

IV. CONCLUSION

This study highlights the integration of Geometer's Sketchpad (GSP) and Realistic Mathematics Education (RME) within the framework of developing interactive visual media for plane geometry instruction. Referring to the research objectives, the results indicate that the designed media not only meets high standards of theoretical validity, based on expert review, but also proves to be practical and positively appreciated by users. Students'

learning experiences underwent significant improvement due to the visual media, which prioritizes exploration, geometric object manipulation, and connection to real-world contexts in accordance with RME principles. Consequently, this approach succeeded in transforming conceptual understanding from abstract to concrete, making it easier to internalize.

Specifically, the application of GSP in geometry learning fostered active student engagement, facilitated the understanding of spatial representations, and made mathematical abstractions more accessible through concrete visualization. The practicality of the media is also reflected in its ease of use, flexibility of access, and relevance to the diverse needs of students in higher education.

The primary contribution of this research to the advancement of mathematical science lies in the innovative media development model that merges the sophistication of visual technology with the power of RME-based contextual pedagogy. This approach tangibly overcomes the limitations of traditional approaches in geometry instruction and reinforces the argument that the integration of interactive software can substantially enhance the quality of mathematics learning. The emerging theoretical implication is the strengthened need for instructional design that combines technology, active engagement, and learning experiences relevant to real life.

Key novel findings derived from this study include: (1) The combination of GSP and RME in visual media is proven valid and highly feasible for application in plane geometry instruction; (2) This media effectively bridges the gap between abstract understanding and students' concrete experiences, directly impacting the improvement of their conceptual understanding; and (3) Innovation based on the collaboration between contextual pedagogy and technology constitutes a crucial strategy in the development of future-oriented mathematics learning media.

This study offers the following recommendations for educational practice, scientific development, and future research: Mathematics lecturers are encouraged to integrate GSP-based interactive visual media into instruction, particularly for plane geometry, to strengthen students' understanding and spatial skills. Structured training and mentoring programs are also necessary to ensure the optimal and consistent implementation of this media; Future development directions should focus on utilizing broader GSP features for various topics, such as solid geometry and trigonometry. generally, the findings of this study can serve as a foundation for formulating technology-based instructional design theories relevant to other educational levels; It is recommended that subsequent research examine the quality of learning outcomes, knowledge retention, and the development of students' higher-order thinking skills regarding the long-term use of this media. Comparative studies on the efficiency of this media versus others, as well as the influence of student learning styles, should be explored further to broaden understanding; and Future research should also consider real-world implementation

challenges, such as infrastructure availability, educator readiness, and the diversity of students' technological proficiency. Synergistic efforts among policymakers, media developers, and educators are essential to ensure the sustainability and dissemination of this innovation within the educational environment.

In conclusion, the development of interactive visual media resulting from the integration of GSP and the RME approach in plane geometry has demonstrated a tangible positive contribution to mathematics learning in higher education. Cross-sector collaboration and sustainable commitment are vital for this innovation to be beneficial and to expand further for the advancement of mathematics education in Indonesia.

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