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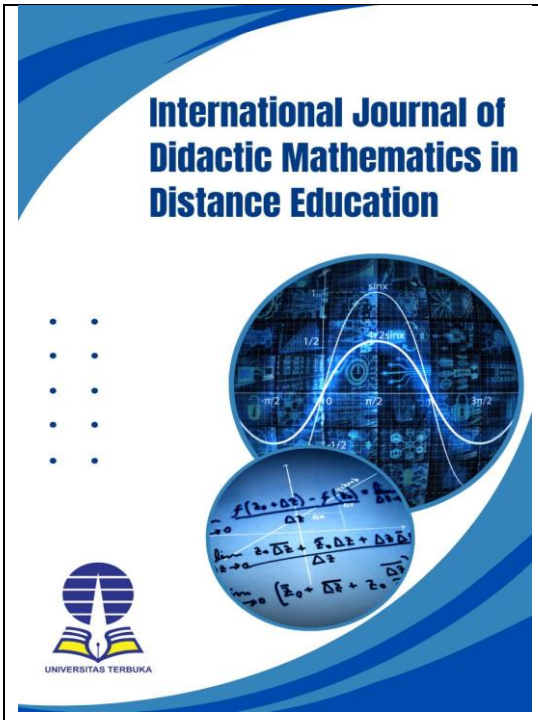

Interactive GeoGebra media embedded in student worksheets: a design approach to foster mathematical engagement in 3D Geometry

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Interactive GeoGebra media embedded in student worksheets: a design approach to foster mathematical engagement in 3D Geometry

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Abstract
Geometry, particularly three-dimensional (3D) geometry, is often perceived by students as abstract and difficult, resulting in low engagement and interest. Addressing this issue, the present study aimed to design interactive learning media using GeoGebra integrated with Student Worksheets to enhance students' interest in learning 3D geometry. The research employed a Research and Development (R&D) methodology, encompassing the stages of needs analysis, design, development, implementation, and evaluation. The participants were 30 students from a public high school in Cianjur, Indonesia, who were involved in mathematics instruction on 3D geometry topics. Data were collected through student response questionnaires assessing the usability and effectiveness of the developed media. The findings indicate that the GeoGebra-based Student Worksheet media met validity and practicality criteria, with students responding positively to its use. They reported that the interactive features of the media facilitated better conceptual visualization and significantly increased their interest in learning. Furthermore, implementation strategies—such as teacher demonstrations, collaborative group work, and guided class discussions—proved effective in mitigating the abstractness of 3D geometry. This research contributes to the growing body of literature on technology-enhanced mathematics instruction by offering a practical and engaging learning solution. The integration of GeoGebra-based Student Worksheets is therefore recommended as an effective pedagogical tool to foster students' mathematical interest and conceptual understanding, especially in abstract topics like three-dimensional geometry.

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1. Introduction

Geometry is one of the branches of mathematics that plays an important role in the development of spatial thinking abilities, problem-solving skills, and the application of mathematical concepts in everyday life (Buckley et al., 2019; Fatihah et al., 2023). Geometry helps students understand the relationships between objects and natural phenomena and provides a foundation for understanding various other disciplines such as physics, engineering, and architecture (Huckstep, 2003). However, despite its importance, geometry is often considered abstract and difficult for students to comprehend, which leads to a lack of interest in its study. Students often face challenges in understanding geometric concepts, such as difficulty distinguishing the elements of solid figures, providing relevant examples of concepts, or applying mathematical concepts to solve complex problems (Zulnaidi et al., 2017).

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Difficulties in learning three-dimensional geometry often occur because students experience obstacles in visualising and understanding the spatial relationship between elements of a space, such as points, lines, and planes (Alghadari et al., 2020; Sudirman et al., 2023). In addition, research by (Hartati et al., 2024) found that students made errors in visualising problems (34.50%), analysing (23.54%), and deducing (22.54%) when solving three-dimensional geometry problems. The causative factors include lack of accuracy in understanding and analysing the problem, errors in interpreting drawings, calculation errors, and lack of care in making conclusions. Similar findings were also reported by (Suciati et al., 2023), who emphasised that students' errors in solving three-dimensional geometry problems are closely related to spatial ability.

Another issue stems from internal factors such as students' lack of mental readiness and motivation to learn, as well as low algebraic skills and problem-solving planning abilities. According to Hwang & Hu (2013), obstacles in learning geometry are also influenced by students' low ability to understand geometry problems and to visualize the shapes of solid figures. On the other hand, external factors, such as the teacher's teaching approach not aligning with the characteristics of the students, also contribute to the low interest and academic performance of students in geometry (Ansari et al., 2019). Teaching geometry and creating interest in students is one of the concerns for maths teachers (Fadaee & Ghahramani, 2021).

To address these issues, innovation in teaching methods is crucial. One alternative solution is the use of interactive learning media that incorporates digital technology. GeoGebra, as a dynamic mathematical software, has been proven effective in visualizing mathematical concepts, particularly in geometry (Basri et al., 2025). GeoGebra allows students to manipulate objects, explore the properties of geometry, and understand concepts more intuitively through animations and dynamic manipulations (Zhang et al., 2025). This is in line with Wassie and Zergaw (2019), view that mathematics learning is more effective when students are given the opportunity to manipulate relevant learning tools.

Moreover, the use of GeoGebra in teaching can be integrated with Student Worksheets. Student Worksheets functions as a structured learning guide that helps students learn actively and independently. The integration of GeoGebra with Student Worksheets allows students to not only better understand geometric concepts but also increase their interest in learning mathematics. According to Gurmu et al., (2024), GeoGebra can quickly and accurately generate geometric diagrams, provide clear visual experiences, and allow deeper exploration of the properties of geometric objects. Mahmudi (2011) adds that GeoGebra also facilitates learning evaluation, ensuring that students understand concepts in a more practical and engaging manner.

Several studies have also shown the benefits of using GeoGebra in various mathematical learning contexts. For example, Sugiarni et al., (2024) developed visual media using the GeoGebra application for Linear Program material, which showed an improvement in students' understanding of the topic. Another study by Pratama et al., (2024) developed GeoGebra-based learning media with a basketball context for quadratic function material, which successfully enhanced students' comprehension. Additionally, Septian et al., (2020) demonstrated that the use of Android-based GeoGebra on quadratic equation material improved students' mathematical creative thinking abilities. All these studies support the use of GeoGebra as an effective medium for enhancing students' understanding and interest in learning. GeoGebra is useful as a learning media and can increase students' interest and learning outcomes in learning the material of building spaces (Widyastiti et al., 2024).

This research has novelty compared to previous studies that have utilised GeoGebra in learning three-dimensional geometry, both in the form of learning media (Widyastiti et al., 2024), student worksheets (Yerizon et al., 2021), and integration with investigative questions (Lestari et al., 2025). Several other studies have also proven the effectiveness of GeoGebra in improving the performance and attitudes of students and teachers towards learning geometry (Uwurukundo et al., 2024) and developing teaching materials based on a scientific approach (Karonev, 2017; Sugiarni et al., 2018). However, the novelty of this research lies in designing GeoGebra-based learning media that is systematically integrated with Student Worksheets (LKS) to form a unified learning strategy that is valid, practical, and effective in increasing students' interest in learning and understanding of concepts in three-dimensional geometry material. This approach not only makes use of GeoGebra's interactive features but also directs students' learning activities through LKS

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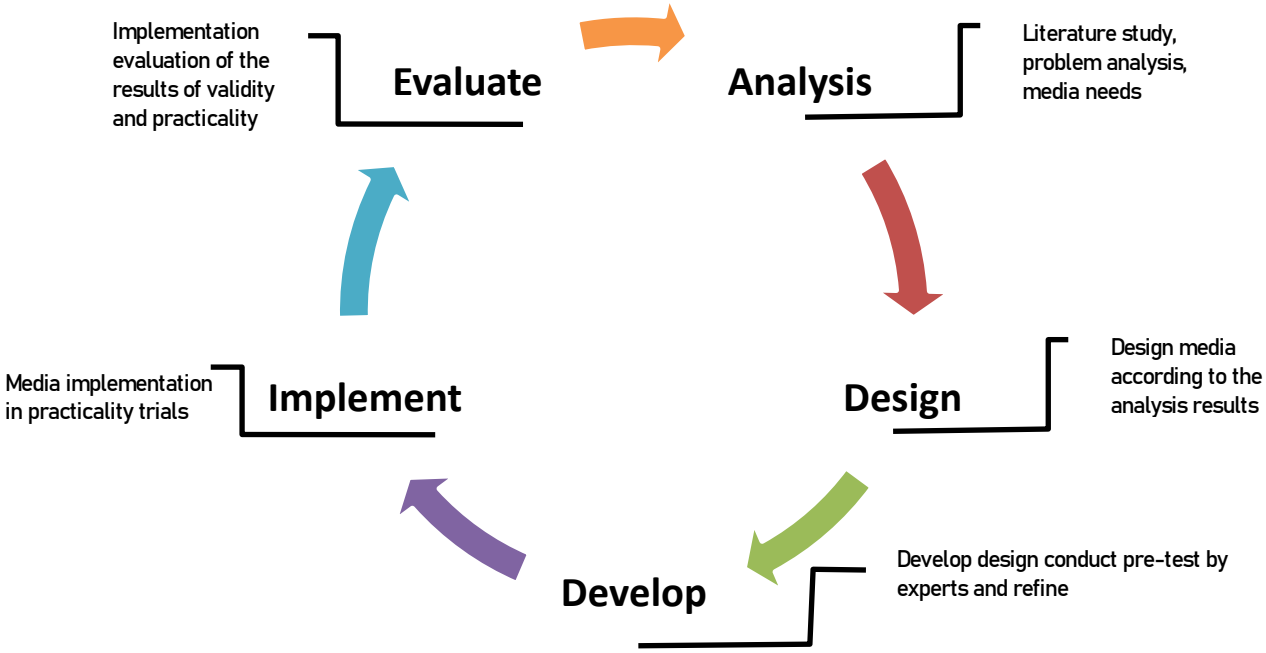
designed according to cognitive needs and spatial visualisation, thus answering the challenges of learning complex geometry more thoroughly. This research aims to design a valid, practical, and effective GeoGebra-based learning media integrated with Student Worksheets to optimize students' interest in learning mathematics, particularly in three-dimensional geometry.

2. Method

The method used in this study is the Research and Development (R&D) method with the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation). According to Creswell (2012), the stages of the ADDIE development model are shown in Figure 1 (Sugiarni et al., 2019).

Figure 1
Stages of the ADDIE Development Model



In the Analysis stage, the researchers conducted a literature review, identified problems in learning three-dimensional geometry, and analyzed students' needs for interactive learning media. The Design stage involved designing GeoGebra-based interactive media that were aligned with the analysis results and integrated with Student Worksheets to enhance student engagement. During the Develop stage, the initial design was developed further, followed by a pre-test involving expert validation to assess the content, practicality, and technical quality, which was then refined based on expert feedback. The Implement stage included the practical application of the media in a classroom setting to examine how students interacted with and responded to the learning tools. Finally, the Evaluate stage focused on evaluating the implementation results by analyzing the media's validity and practicality, thereby determining its effectiveness in fostering students' interest and understanding in three-dimensional geometry.

The subjects in this study consisted of 30 students who took part in mathematics learning on three-dimensional material. They were involved in the development and trial stages of learning media in the form of interactive geogebra media based on Student Worksheets. Various instruments were used to collect the data needed to develop and evaluate GeoGebra media based on Student Worksheets in optimizing interest in learning mathematics. The data were obtained and analyzed using validation questionnaire research instruments, and student response questionnaires. The validation questionnaire was used to determine the feasibility of visual media with the help of the GeoGebra Application which was validated by experts. The student response questionnaire was used to determine the effectiveness of visual media with the help of the GeoGebra Application. To test the feasibility of the answers, a score was given as determined according to Sugiyono (2019) in Table 1.

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Table 1
Criteria for Assessment by Material Experts and Media Experts

Category	Score for Question or Statement
Very suitable	4
Suitable	3
Less Suitable	2
Not Suitable	1

In analyzing the data, researchers calculated the points given by material experts and media experts into a feasibility score obtained from the percentage of the score obtained with the maximum score. If the feasibility percentage value has been obtained, then the next is to indicate the quality predicate of the product made based on a measurement scale using a rating scale assessment. According to the score obtained, it is interpreted into the rating scale score according to Sugiyono (2013) seen in Table 2.

Table 2
Rating Scale Interpretation

Description	Percentage (%)
Very Decent	82 – 100
Feasible	63 – 81
Not Feasible	44 – 62
Very Unworthy	25 – 43

The student response questionnaire used to test effectiveness is closed. This aims to avoid more extensive information. According to Sugiyono (2019), the data from student responses are then calculated based on the Guttman Scale as in Table 3.

Table 3
Guttman Scale for Student Response

Answer	Value
Yes	1
No	0

If the percentage value of effectiveness has been obtained, then the next step is to interpret using the criteria according to Sugiyono (2019) in Table 4.

Table 4
Interpretation of Media Effectiveness Criteria

Description	Percentage (%)
Highly Effective	80 – 100
Effective	60 – 80
Less Effective	40 – 60
Not Effective	20 – 40
Very Ineffective	0 – 20

3. Results and Discussion

3.1 Results

The results of this study, the development of learning media in the form of interactive GeoGebra media based on student worksheets as a step-by-step guide to students in learning three-dimensional material in optimizing students' interest in learning mathematics. The following is a description of the media development process that is adjusted to the ADDIE model.

3.1.1 Analysis

The analysis stage served as the foundational phase of this development research, comprising both literature review and field study activities. The literature review was conducted to gather and synthesize relevant information concerning current issues in mathematics education, with a specific focus on the teaching and learning of three-dimensional geometry. This process included the examination of scholarly journals, curriculum documents, and prior studies to identify students' learning needs, typical cognitive

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challenges associated with 3D geometry, student characteristics during mathematics instruction, and the types of instructional materials commonly used in the classroom.

Complementing the literature review, a field study was conducted to validate and contextualize the findings through direct engagement with the educational setting. This involved classroom observations and semi-structured interviews with a mathematics teacher at a public high school. The field data provided first-hand insights into students' learning behaviors, the instructional strategies employed, and the teacher's reflections on the challenges faced in teaching three-dimensional geometry.

The findings from both sources converged to reveal that students often struggle with spatial reasoning, visualization of geometric objects, and conceptual understanding in 3D geometry. These difficulties were evidenced by both the teacher's observations and students' suboptimal learning outcomes. Moreover, it was found that existing instructional materials were largely static and lacked interactive components that could support students in visualizing abstract geometric concepts. These insights reinforced the urgency of developing interactive, visualization-based learning media—such as GeoGebra-integrated worksheets—to better address the identified gaps and needs in 3D geometry instruction.

3.1.2 Design

The design stage focuses on the development of the learning content, the structure and interface of the GeoGebra-based media, and the preparation of supporting research instruments. This stage is critical in ensuring that the media developed is pedagogically sound, visually clear, and aligned with curriculum standards. The process begins with the careful selection of subtopics from the Three-Dimensional Geometry (3D Geometry) curriculum, specifically those that are known to pose significant conceptual difficulties for students. Selected subtopics include spatial projections, the calculation of distances from a point to a line, a point to a plane, and the visualization of planes intersecting in three-dimensional space. The learning objectives were derived directly from the national curriculum to ensure alignment with the expected student competencies and achievement indicators.

The next step involves designing the structure and interface of the GeoGebra media. The design process includes determining the appropriate format, layout, and interactive features that support the learning goals. Key considerations include the shape, size, and clarity of the geometric visuals, as well as their manipulability. The resulting interface is organized into three main sections: (1) a dynamic 3D visualization pane where students can interact with geometric objects, (2) a problem/prompt panel displaying guided questions or tasks related to the visuals, and (3) a 2D projection panel showing flat representations of the 3D figures to help students bridge spatial and planar understanding.

The media was intentionally designed to support students' mathematical literacy, particularly on the *employing* indicator, which emphasizes the application of facts, rules, procedures, and mathematical structures to solve problems. Interactivity—such as rotation, zooming, and selective visibility of objects—was embedded to strengthen conceptual visualization and cognitive engagement.

Following media design, the Student Worksheet (LKS) was developed to complement the GeoGebra application. The LKS includes instructions, exploration tasks, and reflection questions aimed at reinforcing the interactive experiences provided by the media. The worksheets are sequenced to guide learners from observation to reasoning and application.

Simultaneously, research instruments were prepared to evaluate the validity and practicality of the developed products. These include:

a) Media validation sheets, which assess aspects such as content accuracy, visual clarity, pedagogical alignment, and interactivity;
b) Worksheet validation sheets, which evaluate instructional structure, clarity of tasks, and curriculum relevance;
c) Student response questionnaires, designed to capture learners' perceptions regarding the usability, appeal, and perceived usefulness of the GeoGebra-integrated worksheets;
d) Scoring rubrics, which provide guidelines for assessing student work and responses during the trial phase.

All instruments were constructed based on predefined criteria and indicators drawn from relevant literature and expert recommendations. Prior to implementation, the media, worksheets, and instruments

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were reviewed and validated by expert validators. Suggestions from these validators were used to revise and refine the products until they met the validity threshold required for practical application in classroom settings.

3.1.3 Development

In the previous development stage, all development instruments were prepared. After determining the design, concept, and media creation, it was continued by compiling the Student Worksheet, then compiling the validation sheet and student response questionnaire sheet for GeoGebra media and student worksheets, as well as scoring guidelines on the sheet. The assessment for the instrument is based on the criteria and indicators that have been determined so that the media and instruments will be validated by the validator, then revised until a valid value is obtained.

In the GeoGebra Media and student worksheets that have been designed and saved in are made in .ggb format for GeoGebra and document format for LKS, then development is carried out by including animations, backgrounds, and images related to the explanation of the material. The student worksheet consists of several pages, the worksheet is done using the GeoGebra application.

Based on Table 5, it is known that the validation results of the GeoGebra Application based on student worksheets in terms of presentation feasibility obtained an average combined percentage of the six validators, namely 98.3% with the criteria "Very valid". This proves that the GeoGebra Application based on student worksheets that has been developed has been compiled in accordance with the format and components that must be present in the GeoGebra Application packaged in electronic form. Meanwhile, the validation results of the GeoGebra Application based on student worksheets for each validator using Likert scale measurements are presented in Table 5.

Table 5

Validity of GeoGebra Application based on Student Worksheets

Validator	Empirical Score	Maximum Score	Average Percentage	Validity Criteria
Validator 1	72	75	96 %	Very Feasible
Validator 2	75	75	100 %	Very Feasible
Validator 3	74	75	99 %	Very Feasible
Average Combined Percentage			98, 3 %	Very Feasible

The validation results of the GeoGebra-based Student Worksheet learning media by three expert validators indicate that the developed media is highly feasible for classroom implementation. Validator 1 assigned a score of 72 out of a maximum of 75, resulting in a feasibility percentage of 96%. Validator 2 gave a perfect score of 75 out of 75, equivalent to 100%, while Validator 3 provided a score of 74 out of 75, or 99%. The combined average percentage from all three validators reached 98.3%, which falls within the "Very Feasible" category. These results demonstrate that the media has successfully met the essential quality indicators in instructional material development, including content relevance to the curriculum, clarity of visual presentation, interactivity, and its potential to support students' conceptual understanding of three-dimensional geometry. The consistency across validators also reflects the reliability of the validation process. Therefore, the GeoGebra-based worksheet media can be considered highly appropriate for use in mathematics instruction and is ready for classroom trials or broader implementation with minimal or no revisions required.

As for the validator's suggestions and recommendations, improvements were then made to the Geogebra Application in Table 6.

Table 6

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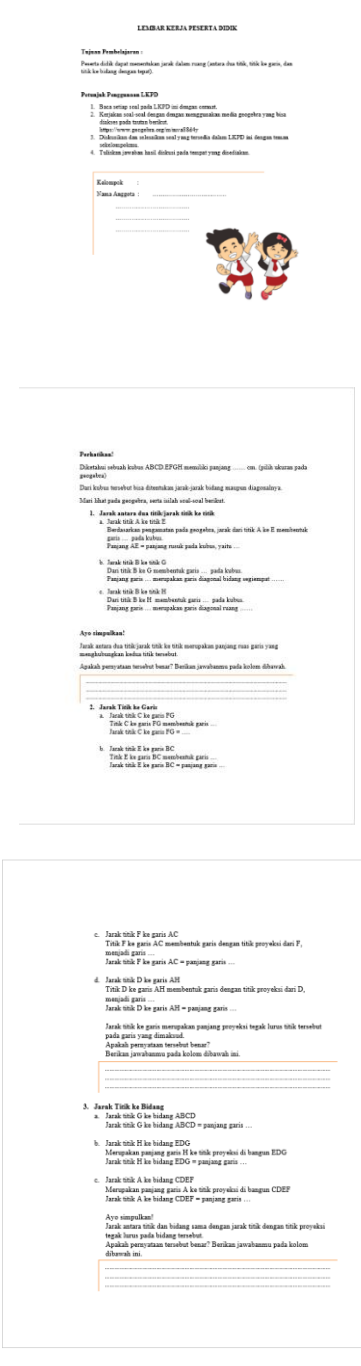
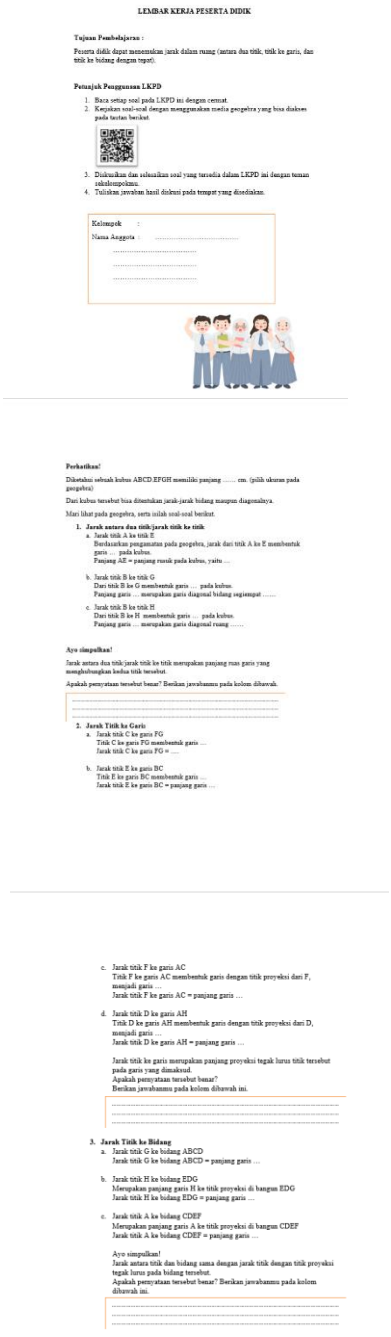
Suggestions and Improvements to Worksheet

Worksheet		Suggestions and improvements
Before Revision	After Revision	
		• On the worksheet, it is better for students to choose the length of the edges of the geometric shapes presented • The contents of the worksheet should be added with true/false answers only • It is better to provide a conclusion at the end with the contents so that students can draw conclusions according to them after trying • The links on the worksheet should be changed to barcodes to make it easier for students • The animated images on the worksheet cover should be adjusted

In GeoGebra media, the page display for three-dimensional material is equipped with a button to show/illustrate questions on the worksheet. In its development, there are comments and suggestions, namely: (1) In the instructional design criteria, there is a suggestion to create a slide that allows students to adjust the size of the presented geometric shapes, (2) In the media display criteria, there is a suggestion

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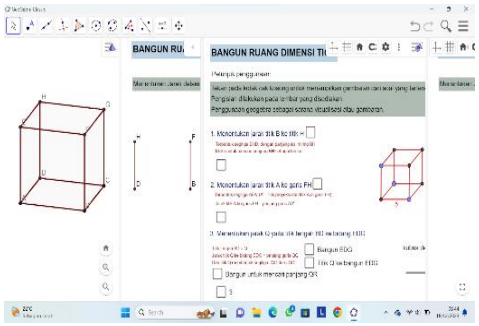
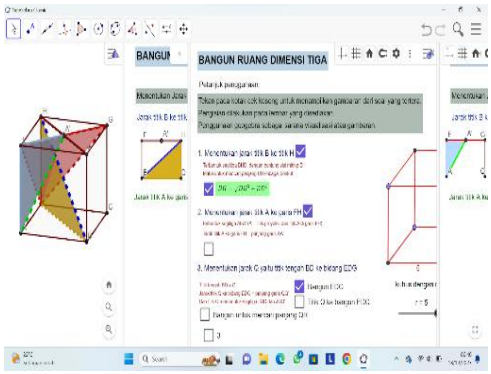
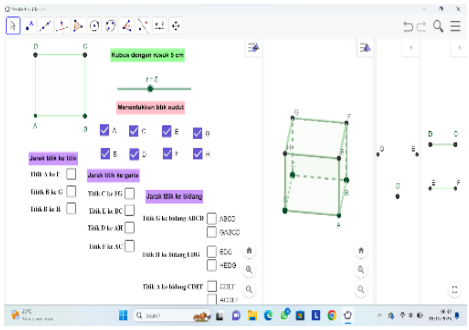
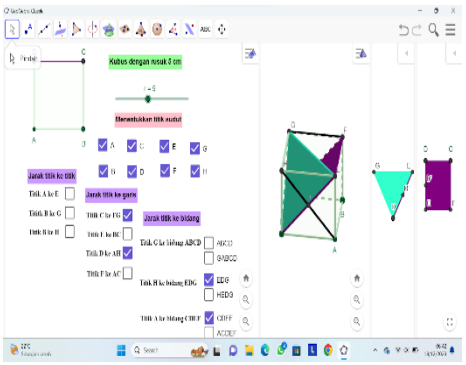
to arrange the displayed material from the simplest concept. The worksheets that have been given input by the validator are then revised. The validity of the GeoGebra-assisted worksheet refers to three aspects (namely content, construction, and language). Table 6 presents the comments and suggestions obtained from the validator, namely: (1) In the instructional design criteria indicator, it is better for students to be able to choose the length of the edges of the geometric shapes presented themselves; the animated image on the worksheet cover is adjusted; the link on the worksheet should be changed to a barcode. (2) In the technical quality criteria indicator, the worksheet is filled in by giving only true/false answers; provide a conclusion at the end with the filling so that students can draw conclusions according to them after trying.

Table 7

GeoGebra Suggestions and Improvements

Geogebra		Suggestions and improvements
Before Revision	After Revision	
 	 	The media design is very good. However, you should organize the GeoGebra display from the simplest concept. Arrange from point to point distance, then point to plane distance, and after that point to plane distance. Make a glide as well so that students can adjust the size of the space presented.

In GeoGebra media, the page display for Three Dimension material is equipped with a button to show/illustrate questions on the worksheet. In its development, there are comments and suggestions, namely: (1) In the instructional design criteria, there is a suggestion to create a slide that allows students to adjust the size of the presented geometric shapes, (2) In the media display criteria, there is a suggestion to arrange the displayed material from the simplest concept. The worksheets that have been given input by the validator are then revised. The validity of the GeoGebra-assisted worksheet refers to three aspects (namely content, construction, and language). Table 6 presents the comments and suggestions obtained from the validator, namely: (1) In the instructional design criteria indicator, it is better for students to be able to choose the length of the edges of the geometric shapes presented themselves; the animated image on the worksheet cover is adjusted; the link on the worksheet should be changed to a barcode. (2) In the technical quality criteria indicator, the worksheet is filled in by giving only true/false answers; provide a conclusion at the end with the filling so that students can draw conclusions according to them after trying.

3.1.4 Implementation

At this implementation stage, after the GeoGebra design and worksheets developed have been tested for validity and have been revised according to the validator's suggestions, the GeoGebra design and

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worksheets were then tested in a limited trial on a small group consisting of 30 high school students. The trial activity began by teaching students to operate Three Dimensions using the GeoGebra application and explaining the activities and components contained in the GeoGebra application by determining the distance from point to point, the distance from point to line, and the distance from point to plane. Furthermore, inviting students to do several learning activities presented in the GeoGebra application, including working on questions/problems on the worksheet and trying to operate GeoGebra, as seen in Figure 2 in groups.

Figure 2

Student Activities in the Implementation of Geogebra Applications Based on Student Worksheets

Students who have worked on the worksheets are invited to present each group. At the end, students work together to conclude the material in accordance with the learning objectives. After completing the learning, students are given a questionnaire on the Student Assessment attitude scale, which is then analyzed to determine the data on the practicality of the implementation of the GeoGebra Application based on worksheets in the form of an average combined percentage of 30 students and its practicality criteria, which are presented in Table 8.

Table 8

Data on Geogebra Media Practicality Results

No.	Respondent	Total Score
1.	Interest in learning mathematics	483
2.	Interest in media using the Geogebra application based on student worksheets	957
3.	Interest in three-dimensional material with the help of Geogebra application media based on student worksheets	301
Total Combined Score		1741
Total Maximum Score		2250
Average (%)		77 %
Practicality Criteria		Practical

The Table 8 presents the results of student responses to the practicality of using GeoGebra-based media integrated into student worksheets for learning three-dimensional geometry. There are three key aspects measured: students' general interest in learning mathematics, their interest in media that utilizes the GeoGebra application within a worksheet format, and their specific interest in three-dimensional material when supported by this media. The total score for "interest in learning mathematics" reached 483, while the score for "interest in the media using the GeoGebra application" was significantly higher at 957. This suggests that the integration of interactive and visual technology such as GeoGebra contributes meaningfully to students' engagement. Meanwhile, the score for "interest in three-dimensional material with the help of GeoGebra-based worksheets" was 301, indicating that while students are interested in the topic, their interest is amplified when supported by appropriate instructional tools. The total combined score from all these categories is 1,741 out of a maximum possible score of 2,250, yielding an average percentage

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of 77%. Based on predetermined criteria, this falls under the category of "Practical", meaning that the media is sufficiently functional and acceptable for use in actual classroom learning.

The implications of these results are significant for the development and implementation of digital mathematics instruction. First, the relatively lower score for general interest in mathematics compared to the high score for interest in media using the GeoGebra application indicates that the instructional design plays a crucial role in shaping student motivation and engagement. GeoGebra's capacity to visualize abstract mathematical concepts—especially in three-dimensional geometry—serves as a powerful support for students who traditionally find such topics difficult and disengaging. Second, the positive response toward the use of student worksheets in combination with the GeoGebra media highlights the importance of structured guidance during interactive learning activities. This blended format allows students to explore, reflect, and apply concepts while benefiting from digital visualization. Additionally, the practicality rating implies that the media is not only engaging but also easy to use and implement from the students' perspective. Overall, these findings support the idea that technology-enhanced learning tools, when well-integrated into instructional design, can improve not just students' understanding but also their interest and motivation. Therefore, the GeoGebra-based worksheet media can be considered a practical and effective tool in teaching complex mathematical topics such as three-dimensional geometry, and its broader application in other areas of mathematics warrants further exploration.

3.1.5 Evaluation

The evaluation stage in the development of the GeoGebra-based application integrated with student worksheets was conducted at the formative evaluation level. This type of evaluation is essential in the development phase to identify areas for improvement prior to wider implementation. The primary goal of the formative evaluation was to enhance the quality and effectiveness of the learning media based on the results of the validity and practicality assessments.

Revisions to the media were made by incorporating suggestions and feedback obtained from expert validators through validation instruments. The formative evaluation revealed that the developed GeoGebra media and worksheets for the Three-Dimensional Geometry topic in Grade XII of senior high school met the criteria of "Very Valid" and "Practical", indicating that the products were of high quality and ready for use in real classroom settings with minor improvements. Specific revisions were carried out in response to validator input across several evaluation dimensions. In terms of instructional design, one of the key suggestions was to add a slider feature in the GeoGebra interface that would allow students to dynamically adjust the size of geometric figures. This addition was intended to support a more interactive and personalized learning experience, especially in visualizing spatial relationships.

Under the media display criteria, suggestions included reorganizing the presentation of materials by arranging them from the simplest to the more complex concepts. This sequencing is pedagogically important to ensure that students build understanding progressively, especially when dealing with abstract geometrical constructs. In the worksheet component, several aspects were also revised. Regarding instructional design, validators recommended adjusting the synchronization between static images and dynamic animations to ensure visual clarity and conceptual coherence. For the communication indicators, it was suggested that the worksheet should include an explicit introduction to foundational geometric elements—namely points, lines, and planes—before progressing to more complex three-dimensional relationships. This step was deemed necessary to reinforce students' conceptual grounding in the topic. In terms of technical quality, improvements were made by adding clear and concise instructions at each stage of the worksheet, particularly when transitioning to tasks that require the use of the GeoGebra application. This was intended to minimize confusion and ensure that students could follow the activities independently with minimal teacher intervention.

Overall, the formative evaluation functioned as a critical step in refining the media before classroom deployment. The evaluative feedback not only strengthened the instructional and technical quality of the learning tools but also aligned the product more closely with student needs and learning characteristics. Consequently, the final version of the GeoGebra-based student worksheet media emerged as a well-validated, practical, and pedagogically robust tool for teaching three-dimensional geometry at the senior high school level.

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3.2 Discussion

GeoGebra is one of the interactive learning media that has been widely used in mathematics learning to improve students' conceptual understanding and learning interest (Hidayat et al., 2024; Radovic et al., 2020; . As a dynamic mathematics software, GeoGebra allows interactive visualization, manipulation of geometric objects, and simulation of abstract mathematical concepts, making them easier for students to understand (Lavicza et al., 2023). This media not only helps students understand the material but also facilitates active learning by allowing them to explore concepts independently. According to Zhang et al., (2023), GeoGebra is very effective in promoting dynamic learning, especially on topics such as geometry and three dimensions, where visualization and interactivity play an important role. The design of the GeoGebra application based on student worksheets on the Three Dimensions material has been proven valid and practical based on the results of expert evaluations and field trials. This application makes a positive contribution to the learning process, especially in optimizing students' learning interest. The use of GeoGebra as an interactive medium provides an interesting learning experience and facilitates a deeper understanding of the Three Dimensions concept. The results of this study are consistent with the findings of Pratama et al., (2024) , which show that GeoGebra is able to improve students' understanding and learning motivation through interactive visualization in mathematics learning.

One of the advantages of GeoGebra-based student worksheets is their ability to integrate technology with structured learning activities. Students can explore geometric objects through simulation and manipulation, so that abstract concepts become more concrete. Research by Sugiarni et al., (2024) also confirmed that GeoGebra-based learning media on various mathematics topics provided significant results in increasing student engagement in learning. With the Student Worksheet guide, students can learn actively and independently while getting direct feedback through interactive activities. Positive feedback from students indicates that this application makes learning more interesting and effective. According to research by Sugiarni et al., (2024) , the integration of technology in mathematics learning, such as the use of GeoGebra, can provide a practical context that is relevant to students' lives. This not only increases students' interest in learning but also helps them understand the relationships between mathematical concepts more thoroughly. Another study by Septian et al., (2020) also showed that technology-based GeoGebra helps students develop critical and creative thinking skills through an exploratory approach to learning. Overall, the results of this study strengthen the evidence that GeoGebra based on student worksheets is an effective learning medium in overcoming obstacles in learning geometry, especially in the three-dimensional material. The use of interactive technology-based media such as GeoGebra makes a significant contribution to improving the quality of mathematics learning. Therefore, this study recommends the widespread application of GeoGebra based on student worksheets to support modern mathematics learning at various levels of education.

Limitations

While the findings of this study highlight the effectiveness and practicality of GeoGebra-based student worksheets in enhancing students' understanding and interest in three-dimensional geometry, several limitations should be acknowledged. First, the scope of the study was limited to a single school context with a relatively small sample size, which may affect the generalizability of the results. The learning environment, teacher guidance, and students' prior knowledge could have influenced the outcomes, making it difficult to conclude that similar results would be achieved in different educational settings or with diverse student populations. Second, the study focused only on formative evaluation stages, without conducting a summative assessment that could provide stronger empirical evidence of long-term impacts on learning outcomes. The research did not include a comparison group, such as students learning with traditional media or other digital tools, which limits the ability to determine the relative effectiveness of GeoGebra-based worksheets against other instructional approaches. Third, although GeoGebra provides strong support for visualization and interactivity, its effective use still depends on students' digital literacy and the availability of adequate technological infrastructure. In classrooms where access to devices or internet connectivity is limited, the implementation of GeoGebra-based media may face practical constraints. Furthermore, the worksheets developed were tailored specifically to the topic of three-

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dimensional geometry, and thus, the results may not directly apply to other mathematics topics without appropriate adjustments. Lastly, while expert validators and student feedback indicated positive responses to the media, the qualitative depth of student engagement, such as levels of critical thinking, creativity, or problem-solving development, was not extensively explored. Future research may benefit from including these cognitive and affective dimensions to gain a more comprehensive understanding of how GeoGebra-based media influences student learning in mathematics.

4. Conclusion

This study has demonstrated that the design of a GeoGebra-based application integrated with student worksheets for the topic of three-dimensional geometry is both pedagogically valid and practically implementable in the classroom. The development process, grounded in curriculum alignment and iterative validation, resulted in an instructional tool that effectively addresses the abstract and spatially demanding nature of three-dimensional geometry. The interactive features of GeoGebra—such as dynamic manipulation, 3D visualization, and immediate feedback—significantly enhanced students' cognitive engagement, enabling them to explore geometric relationships in a more concrete and intuitive manner.

Students responded positively to the use of the GeoGebra-based worksheets, noting improvements in both their motivation and comprehension of complex geometric concepts. These responses affirm that combining structured learning activities with dynamic digital tools can bridge the gap between abstract mathematical theory and students' real-time understanding. In particular, the media proved successful in facilitating students' spatial reasoning, promoting mathematical exploration, and cultivating a more student-centered learning environment. Despite the promising outcomes, the study acknowledges certain limitations and implementation challenges. These include the need for adequate teacher training, access to digital infrastructure, and institutional support for sustained integration of technological media in mathematics instruction. Without addressing these systemic factors, the long-term impact of such innovations may be constrained.

Looking forward, future research is encouraged to explore several key directions. First, the integration of culturally contextualized content—such as local ethnomathematical knowledge—into GeoGebra-based learning can enhance relevance, inclusivity, and student engagement. Embedding local cultural references not only makes learning more meaningful but may also reduce cognitive load by connecting new concepts to familiar contexts. Second, further studies should examine the impact of GeoGebra-based media on higher-order thinking skills, such as critical thinking, problem-solving, and mathematical creativity, through experimental or longitudinal designs. Third, researchers are encouraged to investigate the scalability and adaptability of this approach across various educational levels and learning environments, including under-resourced schools or remote learning contexts.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. The research was conducted independently, with no financial, personal, or institutional influences affecting the objectivity of the study's outcomes.

Contributor

Author 1: Conceptualization, Methodology, and Writing -Original Draft.
Author 2: Design Geogebra, Formal analysis.

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Author 3: Resources, Data Curation, Formal analysis.
Author 4: Review & Editing.
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