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Development of GeoGebra-Based Interactive Learning Media on Gradient Material for Junior High School Students

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ABSTRACT

This study aimed to develop GeoGebra-assisted interactive learning media on the topic of gradients for junior high school students that are valid and practical for use in mathematics learning. This research employed the Research and Development (R&D) method using the 4D model, which consists of the define, design, develop, and disseminate stages. The trial subjects consisted of 15 eighth-grade students of SMP Negeri 1 Tanjung Pura. The research instruments included media expert validation sheets, material expert validation sheets, and student response questionnaires. The results showed that the developed media met the validity criteria based on the media expert validation results with an average score of 3.61 and the material expert validation score of 3.66. In addition, the media received positive responses from students with an average score of 3.63, indicating that it was practical for use in learning activities. The GeoGebra-assisted interactive learning media was able to help students understand the concept of gradients visually and interactively. Therefore, the developed media is feasible to be used as an alternative mathematics learning medium in junior high schools.

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INTRODUCTION

Mathematics is one of the essential subjects in education because it plays an important role in developing students' logical, critical, systematic thinking, and problem-solving skills. Mathematics learning is not only oriented toward computational abilities but also toward understanding concepts and applying them in everyday life. However, mathematics learning in schools still faces various challenges, particularly in delivering abstract concepts to students (Hidayat & Marlina, 2021). These conditions cause many students to experience difficulties in understanding mathematical material deeply, especially at the junior high school level.

One of the mathematics topics often considered difficult by junior high school students is gradients. The topic of gradients requires students to understand the relationship between changes in coordinate values and the slope of a line, both symbolically and visually. In classroom practice, students frequently encounter difficulties in determining the gradient of a line through two points, understanding the properties of gradients, and connecting the concept of gradients with graphical representations. According to Rahman and Yusuf (2021), students' difficulties in understanding mathematical concepts are often caused by low visualization abilities and limited student involvement in the learning process. In addition, learning activities that are still dominated by lecture methods and textbook usage tend to make students passive, resulting in less optimal conceptual understanding (Lestari, 2022).

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Based on preliminary observations conducted at SMP Negeri 1 Tanjung Pura, it was found that most students experienced difficulties in understanding the concept of gradients and determining relationships between points on the coordinate plane. Students tended to memorize formulas without understanding the actual meaning of the concepts. Conventional learning that lacks the use of visual and interactive media makes it difficult for students to imagine changes in line slopes dynamically. Hidayat and Marlina (2021) stated that limitations in visualization during mathematics learning can hinder the development of students' conceptual understanding, especially in topics requiring visual representation and exploration of mathematical objects.

The development of information and communication technology provides great opportunities to create more effective and engaging mathematics learning innovations. One form of such innovation is the use of interactive learning media based on digital technology. Interactive learning media can create learning experiences that are more active, enjoyable, and student-centered (Sinaga, 2023). The use of interactive media can also help students understand abstract concepts through more realistic visualizations and simulations (Putri, 2024). Therefore, the integration of technology into mathematics learning has become an important necessity in supporting 21st-century learning.

One of the software programs widely used in mathematics learning is GeoGebra. GeoGebra is dynamic mathematics software capable of integrating geometric, algebraic, graphical, and numerical representations simultaneously. GeoGebra enables students to manipulate mathematical objects directly so that they can explore mathematical concepts more interactively and deeply (Setiawan et al., 2023). The use of GeoGebra in mathematics learning can also help students understand relationships between concepts through dynamic visualizations and interactive simulations (Surya & Ristanto, 2022).

Various previous studies have shown that the use of GeoGebra has a positive impact on mathematics learning. Rahman and Yusuf (2021) stated that the use of GeoGebra significantly improves students' mathematical conceptual understanding. Research conducted by Febrianti et al. (2024) showed that GeoGebra effectively improves students' spatial abilities in transformation geometry material. In addition, Wibawa and Astrilia (2025) found that discovery learning assisted by GeoGebra could increase student engagement in independently exploring mathematical concepts. Research by Kurniawan and Ulfah (2023) also showed that GeoGebra-based learning media are more effective than conventional media in increasing students' interest and participation during the learning process.

The utilization of GeoGebra not only helps students understand mathematical concepts but also supports teachers in creating more innovative learning experiences. Hazira and Pujiastuti (2024) stated that the use of GeoGebra applets can help students solve Higher Order Thinking Skills (HOTS) problems through independent concept exploration. Furthermore, Nurcahyo et al. (2021) explained that the integration of GeoGebra with digital classrooms allows teachers to monitor students' learning activities more effectively. This indicates that GeoGebra has significant potential to be developed into interactive learning media that support modern mathematics learning.

Although various studies have developed GeoGebra-assisted learning media, most research has focused on geometry transformations, systems of linear equations in two variables, and solid geometry topics. Research specifically developing GeoGebra-based interactive learning media on gradient material for junior high school students is still limited. In addition, media developed in previous studies generally have not integrated interactive simulations and independent exercises

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accessible through Android devices. Irvan (2024) emphasized that the development of mathematics learning media needs to be adapted to technological advancements and the characteristics of 21st-century students to make learning more relevant and meaningful.

The development of interactive learning media also needs to consider design, appearance, and ease of use so that students become more interested in learning. According to Anjaswari (2024), interactive learning media designed attractively and contextually can improve students' learning motivation. In addition, Wahyuni and Amelia (2025) stated that the successful implementation of technology-based media is greatly influenced by teachers' readiness to optimally utilize learning technology. Therefore, the development of GeoGebra-based media needs to be designed systematically so that it can be easily used by both teachers and students.

Based on these problems, it is necessary to develop GeoGebra-based interactive learning media that can help students understand the concept of gradients visually, dynamically, and interactively. The developed media are expected to facilitate students in exploring relationships between points, changes in line slopes, and the application of gradient concepts in solving mathematical problems. In addition, the use of interactive media is expected to increase student engagement in learning so that the learning process becomes more interesting and meaningful.

Therefore, this study aims to develop GeoGebra-based interactive learning media on gradient material for junior high school students that meet the criteria of validity and practicality for use in mathematics learning. The results of this study are expected to become an alternative innovative learning medium that supports the integration of technology in 21st-century mathematics learning.

RESEARCH METHOD

This study employed a Research and Development (R&D) approach aimed at producing GeoGebra-based interactive learning media on the topic of gradients for junior high school students that are valid and practical for use in mathematics learning. The development model applied in this study was the 4D model developed by Thiagarajan, which consists of four stages: define, design, develop, and disseminate.

The study was conducted at SMP Negeri 1 Tanjung Pura during the second semester of the 2025/2026 academic year. The trial subjects consisted of 15 eighth-grade students selected purposively by considering variations in students' academic abilities. In addition, the study involved expert validators consisting of two media experts and one mathematics teacher as a material expert.

The first stage, namely define, was conducted to analyze learning needs. This stage included front-end analysis, student characteristic analysis, concept analysis, task analysis, and learning objective analysis. The front-end analysis was carried out to identify problems occurring in mathematics learning, particularly on the topic of gradients. Student analysis aimed to determine students' characteristics and learning needs, while concept analysis was conducted to determine the material to be developed in the learning media.

The second stage, namely design, involved designing the GeoGebra-based interactive learning media. At this stage, test preparation, media selection, format selection, and initial media design were carried out. The media were designed in the form of interactive slides containing

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learning materials, simulations, practice exercises, and interactive navigation so that students could independently explore gradient concepts through computers and Android devices.

The third stage, namely develop, was carried out through expert validation and small-scale trials. Expert validation aimed to determine the validity level of the media in terms of content, appearance, usability, and material suitability. After revisions were made based on validators' suggestions, the media were tested on students to determine their practicality through student response questionnaires.

The final stage, namely disseminate, was conducted by distributing the GeoGebra applet link to students through online learning media so that the media could be used more broadly in mathematics learning.

The research instruments consisted of media expert validation sheets, material expert validation sheets, and student response questionnaires. The instruments used a Likert scale ranging from 1 to 4, where a score of 1 indicated "very invalid," 2 indicated "invalid," 3 indicated "valid," and 4 indicated "very valid."

The data analysis technique used descriptive quantitative analysis by calculating the average scores of validation results and student responses using the following formula:

$$\bar{x} = \frac{\sum x}{n}$$

Where:

- $\bar{x}$ = average score
- $\sum x$ = total score obtained
- n = number of assessors

The average scores were then categorized based on the validity and practicality criteria of the media as presented in Table 1.

Table 1. Validity and Practicality Criteria of the Media

Score Interval	Criteria
3.25 – 4.00	Very Valid/Practical
2.50 – 3.24	Valid/Practical
1.75 – 2.49	Less Valid/Practical
1.00 – 1.74	Invalid/Impractical

The GeoGebra-based interactive learning media were considered feasible for use if they met at least the valid and practical categories based on expert validation results and student responses.

RESULTS AND DISCUSSION

Results

This study produced GeoGebra-based interactive learning media on the topic of gradients for junior high school students. The media development was conducted using the 4D model consisting of the define, design, develop, and disseminate stages. The results obtained at each stage are described as follows.

1. Define Stage

The define stage was conducted to identify learning needs and problems occurring in the mathematics learning process. Based on preliminary observations conducted at SMP Negeri 1

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Tanjung Pura, it was found that students experienced difficulties in understanding the concept of gradients, particularly in determining line slopes and connecting gradient concepts with graphical representations. Learning activities that were still teacher-centered caused students to become passive and merely memorize formulas without deeply understanding the concepts.

The analysis of student characteristics showed that students were more interested in learning activities utilizing visual media and interactive technology. Therefore, learning media capable of dynamically visualizing gradient concepts were needed so that students could understand relationships between points and changes in line slopes more concretely.

At the concept analysis stage, the developed materials included the definition of gradients, gradients of lines through two points, gradients in linear equations, and properties of gradients. Furthermore, the learning objective analysis was conducted to determine the competencies students should achieve after using the GeoGebra-based interactive learning media.

2. Design Stage

The design stage was carried out by preparing the design of the GeoGebra-based interactive learning media on the topic of gradients. The media were designed in the form of interactive slides accessible through computers and Android devices. Each slide contained learning materials, visual illustrations, interactive simulations, practice exercises, and navigation buttons to facilitate students in using the learning media.

The developed media consisted of 11 main pages systematically arranged from simple to more complex materials. In the initial section, the media introduced the concept of gradients related to everyday life. Furthermore, students were directed to understand gradient concepts through the visualization of lines and coordinates on the Cartesian plane. At the end of the media, interactive exercises were provided, allowing students to receive direct feedback on their answers.

a. Initial Display of the Media

The initial page of the media was designed to provide a general overview of the gradient material and instructions for using the media. This page included navigation buttons such as “Start,” “Next,” “Back,” and “Reset,” which helped students operate the media independently. The initial display was designed attractively to increase students’ learning motivation and interest.

Figure 1. Initial Display of GeoGebra-Based Interactive Learning Media

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b. Interactive Simulation Display

In the simulation section, students could observe changes in line slopes dynamically through moving points on the coordinate plane. This interactive simulation enabled students to understand the relationship between changes in coordinate values and gradient values visually and exploratively. The use of simulations in GeoGebra helped students understand the previously abstract concept of gradients more concretely.

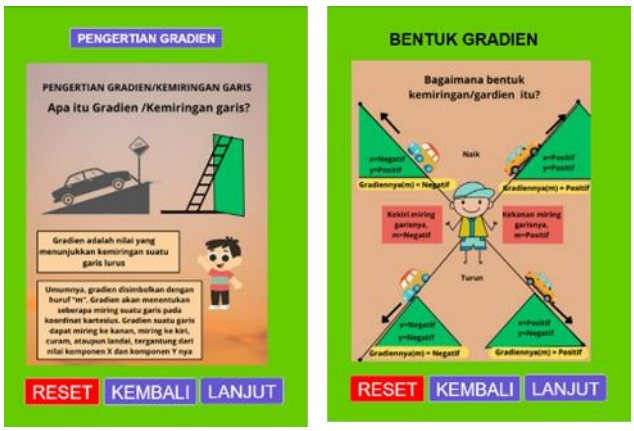

Figure 2. Interactive Gradient Simulation Display Using GeoGebra

c. Interactive Exercise Display

The media were also equipped with interactive exercises to measure students' understanding of gradient material. This section provided practice questions accompanied by answer fields and a "Check" button to automatically verify students' answers. If the answer was correct, the system displayed scores as learning feedback. This feature enabled students to study independently and repeat exercises until they fully understood the concepts.

Figure 3. Interactive Exercise Display in the Media

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The developed learning media using GeoGebra generated an applet link that could be accessed online through computers and Android devices. Therefore, students could use the learning media flexibly both inside and outside the classroom. In addition, the integration of the media with GeoGebra Classroom enabled teachers to monitor students' learning activities while using the learning media.

3. Develop Stage

The develop stage was conducted through expert validation and small-scale trials to determine the validity and practicality levels of the developed media.

Media Expert Validation Results

Media expert validation was conducted to evaluate aspects of media content, appearance, animation, and usability. The results of media expert validation are presented in Table 2.

Table 2. Media Expert Validation Results

Validation Aspect	Average Score
Learning Media Content	3.7
Images and Animation	3.6
Learning Media Usability	3.8
Form and Appearance	3.3
Average	3.61

Material Expert Validation Results

Material expert validation was conducted to assess the suitability of the material with learning objectives, concept accuracy, and the systematic presentation of the material. The results are presented in Table 3.

Table 3. Material Expert Validation Results

Validation Aspect	Average Score
Rationality	3.7
Learning Objectives	3.8
Material	3.8
Appearance	3.5
Presentation Method	3.6
Physical Form	3.6
Average	3.66

The data in Table 3 indicate that the media obtained an average score of 3.66, categorized as very valid. This result shows that the material presented in the media was appropriate for learning competencies and easy for students to understand.

Small-Scale Trial Results

The small-scale trial was conducted with 15 eighth-grade students to determine the practicality level of the developed learning media. The results of students' responses are presented in Table 4.

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Table 4. Student Response Results

Response Aspect	Average Score
Material Presentation	3.64
Language and Appearance	3.62
Average	3.63

Based on the students' responses, the average score obtained was 3.63, categorized as very practical. Students stated that the media were easy to use, attractive, and helpful in understanding gradient concepts through interactive visualization. However, some students suggested that the media should be accessible offline and that image displays should be enlarged when accessed through Android devices.

4. Disseminate Stage

The disseminate stage was conducted by distributing the GeoGebra applet link to students through online learning platforms. The media could be accessed using computers and Android devices, allowing students to learn flexibly both inside and outside the classroom.

Discussion

The results of the study indicate that the GeoGebra-based interactive learning media on the topic of gradients met the criteria of validity and practicality for use in junior high school mathematics learning. The validity of the media was demonstrated through the media expert assessment results with an average score of 3.61 and the material expert validation score of 3.66, both categorized as very valid. The high validity scores indicate that the developed media fulfilled the aspects of content, appearance, usability, and suitability of learning materials. According to Muslim et al. (2023), product validation is an important stage in development research to ensure that the resulting media are appropriate for use in the learning process.

The use of GeoGebra in learning media was able to help students understand the concept of gradients visually and dynamically. Students could directly observe changes in line slopes through interactive simulations, making abstract concepts more concrete. This finding is consistent with the study conducted by Rahman and Yusuf (2021), which stated that GeoGebra effectively improves students' mathematical conceptual understanding through dynamic visualization. Furthermore, Hidayat and Marlina (2021) explained that visualization in mathematics learning plays an important role in helping students develop conceptual understanding and reduce misconceptions related to abstract material.

The developed media also provided opportunities for students to independently explore concepts through simulation features and interactive exercises. Students could manipulate points on the coordinate plane and directly observe changes in line gradients. These exploratory activities support constructivist learning, in which students build their own understanding through active learning experiences. This finding is in line with Surya and Ristanto (2022), who stated that the integration of GeoGebra in mathematics learning can increase exploratory activities and student engagement during the learning process.

The results of student responses showed an average score of 3.63, categorized as very practical. Students stated that the media were easy to use, attractive, and helpful in understanding gradient concepts more clearly. The high positive responses indicate that the use of interactive media can increase students' interest and learning motivation. This finding is supported by Lestari

(2022), who stated that interactive learning media can improve student engagement in mathematics learning because students are not only passive recipients of information but are also directly involved in the learning process.

The developed learning media were also designed similarly to interactive student worksheets, allowing students to learn gradually from understanding basic concepts to solving practice problems. The systematic presentation of the material helped students independently construct conceptual understanding. This finding is consistent with Cahyana et al. (2024), who showed that GeoGebra-based media could improve students' mathematical conceptual understanding through exploration and visualization activities. In addition, Damayanti and Qohar (2019) stated that systematically designed interactive learning media can help students understand mathematical concepts more effectively.

The use of interactive exercise features in the media also provided immediate feedback on students' answers. Students could identify their mistakes and repeat exercises until they obtained correct answers. This feature helped students learn independently and improve their mathematical problem-solving skills. According to Hazira and Pujiastuti (2024), the use of GeoGebra applets in learning can help students solve Higher Order Thinking Skills (HOTS) problems through repeated exploration and independent practice.

In addition to helping students, the use of GeoGebra also supported teachers in creating more innovative and effective learning experiences. The developed media could be implemented through GeoGebra Classroom, enabling teachers to monitor students' learning activities online. This finding is supported by Nurcahyo et al. (2021), who explained that the integration of GeoGebra with digital classrooms facilitates teachers in monitoring students' learning activities and progress during instruction.

The findings of this study also indicate that the use of GeoGebra-based learning media is relevant to the demands of 21st-century learning, which emphasizes the integration of technology into the learning process. According to Sinaga (2023), the utilization of technology in learning can improve students' critical thinking skills, creativity, and digital literacy. Therefore, the development of GeoGebra-based interactive learning media can serve as an alternative innovative mathematics learning approach that aligns with current students' needs.

Nevertheless, the developed media still have several limitations. The media require an internet connection to optimally access the GeoGebra applet, and not all Android devices fully support the interactive features. In addition, this study was limited to the development of media on the topic of gradients and did not measure the effectiveness of the media in improving students' learning outcomes through large-scale experimental studies. Therefore, future studies are recommended to develop GeoGebra-based media for other mathematics topics and examine their effectiveness in improving students' critical thinking skills, problem-solving abilities, and learning outcomes on a broader scale.

Overall, the results of this study indicate that GeoGebra-based interactive learning media can serve as an innovative alternative for mathematics learning that aligns with the needs of 21st-century education. The use of interactive media can create more engaging and active learning experiences and help students understand mathematical concepts more deeply.

CONCLUSION

This study successfully developed GeoGebra-based interactive learning media on the topic of gradients for junior high school students using the 4D development model, which consists of the define, design, develop, and disseminate stages. The developed media were designed as interactive learning tools containing concept visualizations, dynamic simulations, and interactive exercises to help students understand the concept of gradients more concretely and attractively.

The results of the study showed that the developed learning media met the criteria of being highly valid based on the media expert validation results with an average score of 3.61 and the material expert validation score of 3.66. In addition, the results of the small-scale trial with students obtained an average response score of 3.63, categorized as very practical. These results indicate that the GeoGebra-based interactive learning media are feasible for use in mathematics learning on the topic of gradients.

The use of GeoGebra in the learning media was able to help students visualize gradient concepts dynamically through simulations and interactive exploration. The developed media could also increase student engagement in learning because students were able to study independently through exercise features and automatic feedback. Therefore, GeoGebra-based interactive learning media can become an innovative alternative learning medium that supports 21st-century mathematics education.

Nevertheless, this study still has several limitations because the developed media were only focused on the topic of gradients, and their use still requires an internet connection to optimally access the GeoGebra applet. Therefore, future studies are recommended to develop GeoGebra-based learning media for other mathematics topics and to examine the effectiveness of the media in improving learning outcomes, critical thinking skills, and students' problem-solving abilities through experimental studies on a broader scale.

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