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# Developing a GeoGebra-Based Teaching Module on Quadrilateral Area and Perimeter to Enhance Seventh-Grade Students' Critical Thinking Skills

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**ABSTRACT**

**Objective:** Seventh-grade students often need help to grasp the concepts of area and perimeter, particularly when applied to real-world problems requiring critical thinking. This difficulty highlights a need for engaging and effective teaching resources beyond traditional methods. **Method:** This study employed a Research and Development (R&D) approach using the ADDIE model to design, develop, and evaluate a GeoGebra-based teaching module explicitly targeting the area and perimeter of quadrilaterals. The module, designed to foster critical thinking, underwent rigorous validation by media and material experts before being tested for practicality and effectiveness with seventh-grade students. **Result:** The GeoGebra-based teaching module was valid and practical, receiving high scores from expert evaluations and user feedback. More importantly, the module's implementation positively impacted students' critical thinking skills related to area and perimeter, as evidenced by significant improvement between their pre-intervention and post-intervention assessments. **Novelty:** This study provides valuable evidence for the efficacy of GeoGebra-based teaching modules in significantly improving critical thinking skills within a specific mathematical context. It addresses a critical gap in existing educational resources by offering a validated, practical, and effective tool that can be adapted to elevate mathematical understanding and cognitive skills in middle school education.

## INTRODUCTION

Critical thinking is an indispensable skill for students navigating an increasingly complex world. This era demands individuals equipped with robust cognitive abilities and essential skills such as digital literacy, information management, and technological proficiency (Wahyunita & Subroto, 2021). Critical thinking, characterized by applying logical reasoning, enables individuals to effectively analyze information, solve problems, and make informed decisions (Munawaroh & Siswono, 2020). Fostering these skills in students is paramount, and educators play a crucial role in this endeavor. By employing diverse teaching methodologies, including problem-solving activities, discussions, and real-world applications, teachers can cultivate critical thinking within their classrooms (Barak & Shahab, 2023; Chen, 2021; Cruz & Dominguez, 2020; Gleason & Jaramillo Cherrez, 2021; Wang, 2021). This is particularly crucial in mathematics education, where critical thinking manifests in the ability to identify mathematical concepts, analyze relationships, solve problems, and evaluate solutions. Effective utilization of these skills can aid individuals in producing innovative ideas, assessing situations, and making decisions that align with their beliefs and actions. Teachers play a pivotal role in fostering students' critical thinking abilities.

Through information analysis, problem-solving, discussions, debates, and providing concrete examples. By applying appropriate teaching content, processes, and assessment methods, educators can instill confidence in students to express their opinions and apply their critical thinking skills. Critical thinking encompasses the ability to identify mathematical concepts, analyze, establish connections between concepts, solve problems, and evaluate results (Badriyah et al., 2021; Jatmiko et al., 2021; Rahmadita et al., 2021; Rizki et al., 2024; Saphira & Prahani, 2022). Based on these views, the researcher concludes that critical thinking is an art of reasoning that equips individuals with the capacity to create and innovate, reflect on and refine thought processes, analyze and solve problems logically, and respond to situations with alertness and deliberation. Critical thinking is not merely a skill but an intellectual journey leading to a clearer understanding and more purposeful action. In a particular problem posed to seventh-grade students at Madrasah Tsanawiyah Nasional 2 Mojokerto regarding the area and perimeter of quadrilaterals, many needed help determining the perimeter of the given shapes. An example of such a problem is as follows:

***Scenario***

Mr. Agung is renovating his house. He plans to move the front garden to a vacant area behind the house to improve airflow and create a cooler, fresher environment. Before Renovation (Left): The house plan shows the front garden occupying a 2 cm by 2 cm area in the front of the house. The overall house dimensions are 12 cm by 6 cm. After Renovation (Right): The front garden has been moved to the back of the house, occupying the same 2 cm by 2 cm space in the vacant land. The overall house dimensions remain unchanged at 12 cm by 6 cm.

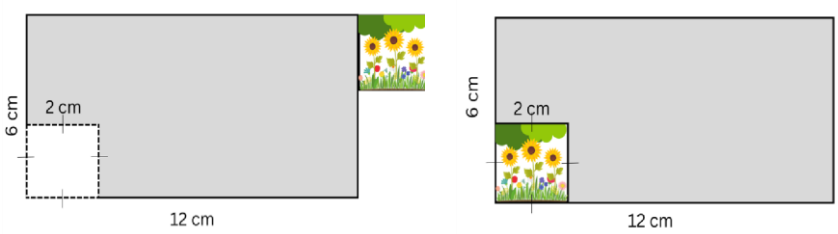


**Figure 1.** Scenario**.**

***Questions***

a) What was the perimeter of the house plan before the renovation?
b) What is the perimeter of the house plan after the renovation?
c) Is there a difference in the perimeter?
d) Why? Provide a clear explanation for your answer.

***Student's Solution's Example (Original)***

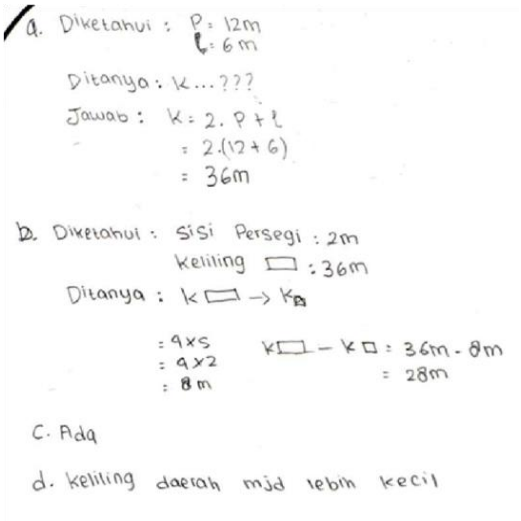


**Figure 2**. Student's solution.

***Student's Solution's Example (English)***

**a. Given:**
**b.** Length (L): 12 m
**c.** Width (W): 6 m
**Asked:** What is the perimeter (P)?
**Answer:**
P = 2 × (L + W)
P = 2 × (12 + 6)
P = 36 m

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d. **Given:**
e. Side of the square (S): 2 m
f. The perimeter of the rectangle is 36 m
What is the perimeter (P) after moving the garden to the back?
**Answer:**
P = 4 × Side of the square
P = 4 × 2
P = 8 m
Then, subtract the square perimeter from the total perimeter of the rectangle:
P = 36 m - 8 m
P = 28 m

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g. **Answer:** Yes, there is a difference.

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h. **Answer:** The perimeter becomes smaller after the garden is moved.

In response (a), students needed to identify the underlying concept or structure of the problem. They proceeded with problem-solving steps without explaining their initial understanding of the concept related to the perimeter (i.e., summing the outer sides of the shape). In response (b), the students failed to conduct an in-depth analysis of the

related aspects, and they needed to clearly define the concept or theorems, such as the principle that the perimeter calculation does not apply to intersecting lines. Although formulas were applied, students needed to integrate various concepts into a coherent solution. For example, they failed to recognize that the garden should be treated as part of the building, forming a complete rectangle. Consequently, the student's answers did not meet the criteria for problem-solving, as they failed to clearly explain their procedures or results (Arzak & Prahani, 2023a, 2023b; Jauhariyah et al., 2021; Pristianti & Prahani, 2022; Suliyanah et al., 2019). Moreover, students should have evaluated their solutions by checking their work or drawing conclusions. The analysis shows that students' critical thinking skills are not yet fully developed. Further efforts are required to help students enhance their critical thinking abilities in mathematics.

Fortunately, the development of information and communication technology (ICT) has positively impacted education. The integration of ICT into learning processes holds the promise of increasing both efficiency and effectiveness when used optimally (Albahri et al., 2024; Cheng et al., 2020; Islam et al., 2024; Mohamed, 2024; Weissler et al., 2021). Efficiency is realized through more accessible access to information and learning resources, while effectiveness improves using more engaging and interactive learning methods such as videos, simulations, and educational games. These methods encourage students to be more active and involved in learning, thereby enhancing their understanding and academic performance (Tambun & Stephani, 2020). The use of technology in education is highly beneficial for students and aims to improve the quality of education in the current era. Governments, schools, and communities must collaborate to support the use of ICT in the learning process. One mathematics topic that can benefit from ICT integration is geometry at the junior high school level, covering topics such as Lines and Angles, Plane Figures, Three-Dimensional Figures, the Pythagorean Theorem, Lines and Planes in Space, Geometric Transformations, and Geometric Coordinates (Curriculum Document of Madrasah Tsanawiyah Nasional 2 Mojokerto, 2023). This study is limited to the area and perimeter of quadrilaterals. The researchers used real-world objects, such as notebooks, banknotes, and tables, to determine the area and perimeter, with most measurements being expressed as decimal numbers due to the precision and accuracy required when measuring real-world objects.

This study introduces a novel approach to teaching the area and perimeter of quadrilaterals by developing and evaluating a GeoGebra-based teaching module designed explicitly for seventh-grade students at Madrasah Tsanawiyah Nasional 2 Mojokerto. The module integrates critical thinking exercises within interactive GeoGebra applets, offering a dynamic and engaging learning experience. This approach addresses a gap in existing resources and provides a practical tool for educators seeking to enhance students' understanding of geometric concepts while fostering critical thinking skills. Research has shown that incorporating technology, such as GeoGebra, into geometry instruction can significantly improve student performance and attitudes (Uwurukundo et al., 2023). Studies have indicated that students who learn with GeoGebra often outperform those who receive traditional instruction, demonstrating the software's potential to enhance academic achievement (Alabdulaziz et al., 2021; Birgin & Topuz, 2021; Fung et al., 2024; Tong et al., 2021; Uwurukundo et al., 2022, 2024). This aligns with the constructivist theory of learning, which emphasizes that students actively construct their knowledge through exploration and interaction with the learning environment. GeoGebra's ability to facilitate dynamic visualization and manipulation of geometric

objects makes it a particularly valuable tool for supporting this type of learning (Febrila et al., 2023).

Furthermore, this study moves beyond simply demonstrating the effectiveness of GeoGebra as a learning tool. It delves into the specific ways in which GeoGebra-based instruction can be structured to promote critical thinking skills. By embedding carefully designed critical thinking exercises within the interactive applets, this research offers a model for developing engaging and cognitively demanding learning experiences beyond the basic visualization and manipulation capabilities often associated with educational software. This nuanced approach to integrating technology and pedagogy contributes to a deeper understanding of effectively leveraging digital tools to foster higher-order thinking skills in mathematics education. GeoGebra's dynamic and interactive nature facilitates students' visualization and exploration of geometric concepts, enabling them to engage in deeper analysis and develop a better understanding of the subject matter (Uwurukundo et al., 2023; Sumarauw et al., 2024). This is particularly relevant for complex geometric concepts, such as three-dimensional figures, where visualization can be crucial for comprehension. GeoGebra's user-friendly interface and readily available online resources make it an accessible and practical tool for students and teachers (Susilawati et al., 2024). Research has also shown that incorporating GeoGebra into the classroom can improve teacher attitudes toward technology integration and a greater willingness to use it in their teaching (Puspitasari et al., 2023).

This study aims to answer the following research question: "To what extent does a GeoGebra-based teaching module enhance the critical thinking skills of seventh-grade students at Madrasah Tsanawiyah Nasional 2 Mojokerto while learning about the area and perimeter of quadrilaterals?" The researchers conducted an initial survey using two instruments to establish the need for a module specifically designed to foster critical thinking. Instrument 1 assessed the students' existing critical thinking skills and learning challenges related to the area and perimeter of quadrilaterals. In contrast, Instrument 2 explored their prior experience with GeoGebra and their perceived value of technology integration for developing critical thinking in mathematics. This needs assessment revealed three key findings: (a) Students' critical thinking skills in this subject area were not optimal. (b) There was limited integration of GeoGebra, a tool with potential for promoting critical thinking, in their current mathematics learning. (c) No GeoGebra-based module specifically designed to enhance critical thinking skills related to the area and perimeter of quadrilaterals existed at Madrasah Tsanawiyah Nasional 2 Mojokerto.

Driven by these findings, the researchers developed a GeoGebra-based teaching module that embeds critical thinking prompts and exercises within interactive GeoGebra applets, fostering a dynamic and engaging learning experience. The module's effectiveness in enhancing critical thinking skills will be assessed using a mixed-methods approach, combining quantitative data (e.g., pretest and post-test scores, N-Gain analysis, which measures the growth in critical thinking skills) and qualitative data (e.g., observations of student engagement with critical thinking tasks, student and teacher feedback on the module's impact on critical thinking). The study has three main objectives: (a) Develop a GeoGebra-based teaching module for seventh-grade students that follows the ADDIE model to enhance critical thinking skills. (b) Develop a valid, practical, and effective GeoGebra-based teaching module that promotes critical thinking. (c) Observe measurable improvements in students' critical thinking skills following the implementation of the GeoGebra-based teaching module. The results and discussion

section will directly address the research question, examining the collected data to determine how the GeoGebra-based module successfully enhances students' critical thinking skills related to the area and perimeter of quadrilaterals.

## RESEARCH METHOD

This study adopts the Research and Development (R&D) approach. The research model used is the ADDIE model developed by Branch (2009). This model comprises five stages: Analysis, Design, Development, Implementation, and Evaluation (Rizki et al., 2024). This model was chosen due to its systematic approach, which includes evaluation and revision at each stage, ensuring the validity of the final product. Furthermore, the ADDIE model is both simple and methodical in its implementation. In this study, the researcher developed a teaching module on the area and perimeter of quadrilaterals integrated with GeoGebra, incorporating critical thinking questions. The ADDIE design model is illustrated in Figure 1.

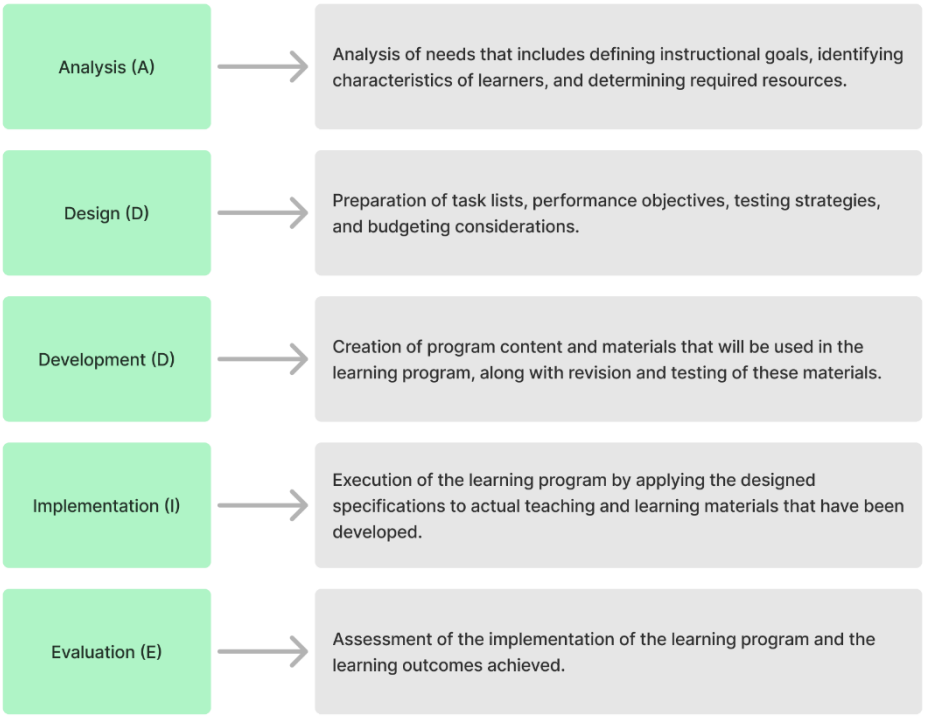


**Figure.** ADDIE development model (Branch, 2009).

### *Adaptation of the ADDIE Development Model*

This study employs the ADDIE development model as outlined by Branch (2009). The research and data collection were conducted at Madrasah Tsanawiyah Nasional 2 Mojokerto, located at Jalan Sambiroto No. 112, Sooko District, Mojokerto Regency, East Java. The subjects of this development research were 32 students from class VII D. A performance and need analysis were carried out to develop a GeoGebra-based teaching module focused on the area and perimeter of quadrilaterals and enhancing critical thinking skills. This needs analysis evaluated the students' critical thinking abilities, learning needs, objectives, characteristics, and the existing learning conditions. The instrument for assessing the needs of teaching module facilities was provided to the head

of the library at Madrasah Tsanawiyah Nasional 2 Mojokerto. Additionally, interviews were conducted with five mathematics teachers from the school to determine the necessity and significance of GeoGebra-based teaching modules in improving students' critical thinking abilities.

During the design phase, Teaching Modules and Learning Implementation Plans were prepared based on the Merdeka Curriculum. The process began with selecting a title, preparing the layout for the GeoGebra-based module on quadrilateral area and perimeter, gathering references, designing GeoGebra applets that incorporate critical thinking questions, identifying essential competencies, and outlining objectives, learning activities, and the module's writing format. The lesson plan comprised general information (such as identity, facilities, learning outcomes, P5P2RA, target participants, and learning model) and core components (including learning objectives, meaningful understanding, triggering questions, and Criteria for Completion of Learning Objectives).

In the development stage, the teaching module was produced in print, featuring a QR code for accessing the GeoGebra applet. The module was designed to be engaging, varied, interactive, and equipped with both text and images—the preparation of the module adhered to a predetermined writing format. Before being field-tested, the module was validated by experts in GeoGebra and the subject matter to gather feedback for further development and refinement. The researchers employed a "one group pretest and post-test" design during the implementation stage. In this design, a pretest was administered before applying the developed module, followed by a post-test to measure the learning outcomes accurately. The pretest (O1) was given as an initial test, followed by two exercises (treatments), namely X1 and X2. After the treatments, a post-test (O2) was conducted as a final assessment to measure the learning outcomes after using the developed module.

Evaluation within the ADDIE model involved determining criteria, selecting appropriate tools, and conducting the evaluations. The goal was to analyze the practicality and effectiveness of the developed module during its implementation stage and to make product revisions based on the results from the field trials. The development of GeoGebra-based teaching media on quadrilaterals' area and perimeter involved quantitative and qualitative data. Quantitative data consisted of numerical scores obtained from the average responses on questionnaires filled out by media experts, content experts, language experts, practitioners, and students. Qualitative data included descriptive feedback in the form of comments and suggestions gathered during the validation and trial processes.

The data collection instruments used in this study included observation, interviews, questionnaires, and tests. Questionnaires were utilized to collect product quality data and trial participants' responses. The quality of the product, as assessed by validators/experts, was measured using an evaluation sheet. The response instrument targeted the students of class VII D at Madrasah Tsanawiyah Nasional 2 Mojokerto during the learning process involving quadrilaterals. The effectiveness of the product was measured through testing, specifically pretests and post-tests. The pretest measured the students' initial abilities, while the post-test assessed the learning outcomes after using the developed media. The pretest and post-test results were compared to determine any significant differences using a one-sided t-test, the N-Gain score, and the N-Gain percent test, calculated using SPSS 29.0.

Data analysis techniques employed in this study included validity, practicality, and effectiveness tests. The validity test used score guidelines and product validity criteria assessed by media and content experts. The product was considered feasible if it achieved a minimum score within the 61 ≤ score ≤ 80 range. The practicality test involved scoring responses based on the criteria of Very Good (5), Good (4), Less Good (3), and Very Less Good (1), followed by calculating the percentage score (instruments 7 and 10). The effectiveness test used a one-group pretest-post-test design, involving only the experimental group that received the X treatment. The pretest (Y1) and post-test (Y2) scores were measured, with the module deemed adequate if the students' post-test scores fell within the Proficient (71-90) and Advanced (91-100) categories, according to the specified criteria.

## RESULTS AND DISCUSSION

### *Results*

A baseline analysis of students' existing understanding of the area and perimeter of quadrilaterals was conducted to assess the potential impact of the GeoGebra-based teaching module's potential impact. This baseline data is crucial for addressing the research question of the module's effectiveness in enhancing critical thinking skills. The analysis revealed that students demonstrated a strong understanding of identifying familiar quadrilateral shapes (100%), but their grasp of other key concepts was less robust. Specifically, only 68.125% of students could accurately describe the characteristics of quadrilaterals, 72.5% could distinguish between the concepts of area and perimeter, and 76.875% could recall the relevant formulas. While providing real-life examples yielded the highest success rate (78.125%), the average overall understanding was 79.125%. This suggests that although students possess some foundational knowledge, there is a clear need for improvement, particularly in areas requiring deeper conceptual understanding and critical thinking, which the GeoGebra-based module aims to address.

Moreover, the needs analysis for GeoGebra-based teaching modules revealed that only 12% of relevant modules are available in the school library. Interviews with five mathematics teachers further emphasized the necessity for developing GeoGebra-based teaching modules focused on area and perimeter that incorporate critical thinking questions. These modules are deemed essential for enhancing the learning outcomes of seventh-grade students, particularly in fostering critical thinking skills. The design of the teaching module was developed in alignment with the planned development canvas. The module includes content and instructions tailored for both teachers and students, teacher-specific material, and student worksheets that integrate QR codes linked to GeoGebra applets containing critical thinking exercises. The module is formatted as a book with dimensions of 21 cm x 29.7 cm (A4) and a thickness of 30 pages. In terms of development, the module underwent assessment by material experts, who acted as validators. They evaluated the module based on its alignment with the curriculum, clarity, completeness, relevance to real-life applications, student engagement, appropriate use of language, visual and media quality, and the effectiveness of the evaluation tools. These criteria were consolidated into three main aspects: content feasibility, presentation feasibility, and overall feasibility, with the module receiving a high validation score of 92.1%.

Media experts also validated the teaching module by assessing its visual quality, media appropriateness, interactivity, clarity, consistency, compatibility with technology, accessibility, and the provision of feedback. They concluded that the module is visually

appealing, supports comprehension, fosters interaction, is easy to read, consistent, compatible with students' devices, accessible to all students, and provides constructive feedback. The media validation resulted in an even higher score of 98.38%. Based on these validation results, the GeoGebra-based teaching module on the area and perimeter of quadrilaterals has been deemed suitable for use in mathematics instruction at Madrasah Tsanawiyah Nasional 2 Mojokerto.

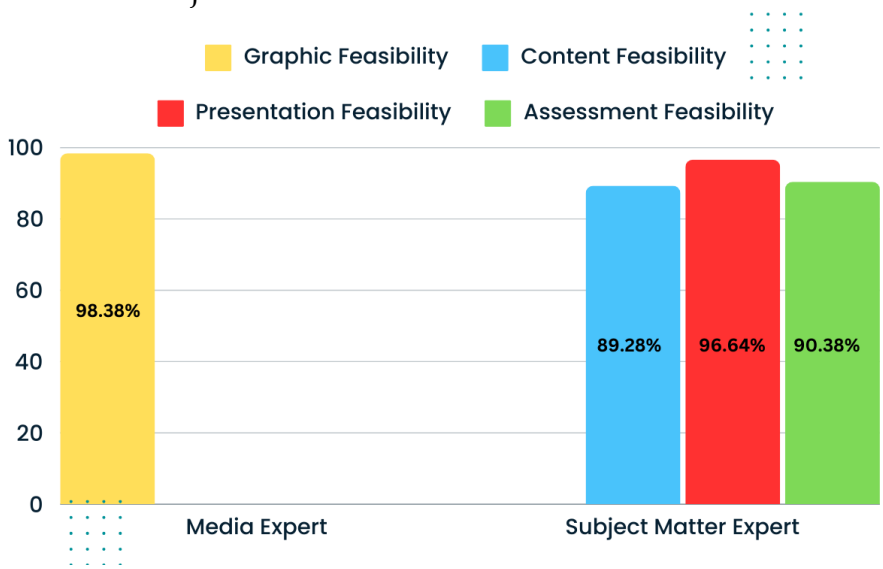


**Figure 2.** Media expert and subject matter expert validation results.

The implementation of the GeoGebra-based teaching module was evaluated through two trial stages. In the first trial, conducted with 8 students from class VII A, the average score achieved was 88.87. According to the Learning Objective Completion Criteria rubric, this score falls within the "Capable" interval (71-90), indicating that the students generally understood the material. In the second trial, involving 32 students from class VII D, the average score was slightly lower at 87.35. Despite the decrease, this score still falls within the "Capable" interval, demonstrating that the module remains effective in enhancing students' critical thinking skills. The practicality of the teaching module was assessed based on several criteria: ease of use, understandability, and completeness received a score of 83%; suitability for time was rated at 81.79%; flexibility and student involvement were scored at 83.16%; time effectiveness and technology suitability received 86.90%; and evaluation and feedback were rated at 87.72%. The overall average practicality score from these criteria was 84.5%. These results indicate that the module is practical and effective in supporting learning. Further analysis of the practicality test revealed specific details: student interest and appearance received a score of 83%; the use of the modules was rated at 81.79%; material and learning outcomes were scored at 83.16%; time was evaluated at 86.90%; and evaluation methods received a score of 87.72%. The module is considered practical, with average scores of 70% and 89%. In conclusion, the GeoGebra-based teaching module on the area and perimeter of quadrilaterals, which incorporates practical critical thinking questions, is deemed both effective and practical. This module serves as a valuable learning resource for students, enhancing their critical thinking skills and overall learning outcomes.

**Table 1.** The module of practicality test results.

| No. | Practicality Indicator | Practicality Score | Criteria |
|---|---|---|---|
| 1. | Ease of use, understandability and completeness | 83.00% | Practical |
| 2. | Conformity to time | 81.79% | Practical |
| 3. | Flexibility and student engagement | 83.16% | Practical |
| 4. | Time effectiveness and technology suitability | 86.90% | Practical |
| 5. | Evaluation and feedback | 87.72% | Practical |
| | **Average** | **84.51%** | **Practical** |

The GeoGebra-based teaching module demonstrates high practicality across all evaluated aspects, with an average score of 84.51%, indicating its suitability for effective classroom implementation. This study's evaluation (E) phase involved the implementation of pretests and post-tests to assess the effectiveness of the GeoGebra-based teaching module. The evaluation used a one-tailed t-test through paired sample t-tests to compare the average scores between the pretest and post-test results, with no control group involved. The analysis was conducted using SPSS version 29.0. The paired sample t-test was employed to determine whether there was a significant difference in the average scores between the two paired samples—specifically, the same group of students' scores before (pretest) and after (post-test) the intervention with the GeoGebra-based module. The pretest average was 65.0625, while the post-test average increased significantly to 88.6250. This substantial increase in the average scores from the pretest to the post-test suggests that the use of the GeoGebra-based teaching module significantly positively impacted students' understanding and their critical thinking skills related to the area and perimeter of quadrilaterals. The statistical results confirm the module's effectiveness in enhancing students' learning outcomes. The paired sample T-Test results are as in Table 2.

**Table 2.** Paired sample statistics

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | Pretest | 65.06 | 32 | 4.62 | .81 |
| | Post-test | 88.62 | 32 | 5.08 | .89 |

The GeoGebra-based teaching module significantly increased average test scores, from 65.06 on the pretest to 88.63 on the post-test. The average pretest score was 65.06, while the post-test scores significantly increased to 88.62, indicating substantial improvement. The sample comprised 32 paired observations. The standard deviation for the pretest was 4.62, and for the post-test, it was 5.08, suggesting a relatively consistent distribution of data between the two assessments. The standard error of the mean for the pretest was 0.81, and for the post-test, it was 0.89, reflecting a similar level of variability in the mean estimates between the pretest and post-test scores. This analysis demonstrates a significant enhancement in students' performance from the pretest to the post-test, with the statistical measures indicating a robust and reliable improvement across the sample.

**Table 3.** Correlation of paired samples.

| | | N | Correlation | Significance | |
|---|---|---|---|---|---|
| | | | | One-Sided p | Two-Sided p |
| Pair 1 | Pretest & Post-test | 32 | .523 | .001 | .002 |

The analysis revealed a positive and statistically significant correlation between the pretest and post-test scores ($r = .523$, $p < .005$). The results indicated a positive and statistically significant relationship or correlation between pretest and post-test scores. This implies that an increase in one variable tends to be followed by an upsurge in the other.

**Table 4.** Paired sample test.

| | Paired Differences | | | | | t | df | Significance | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | One-Sided p | Two-Sided p |
| | | | | Lower | Upper | | | | |
| Pair Pretest – Post-test | -23.56 | 4.75 | .84 | -25.27 | -21.84 | -28.0 | 31 | <.001 | <.001 |

The paired samples t-test showed a statistically significant difference between the pretest and post-test scores ($t(31) = -28.01$, $p < .001$), indicating a significant improvement in scores after the intervention. The mean difference between the pretest and post-test scores was -23.56, with a standard deviation of 4.75 and a standard error of the mean of 0.84. The 95.00% confidence interval for the difference ranged from -25.27 to -21.84. Both one-way and two-way significance levels were less than 0.005, indicating statistically significant results at the 99.90% confidence level. This confirms a significant difference in scores between the pretest and post-test, leading to the acceptance of Hypothesis H1. The N-Gain Score Test was conducted to assess the intervention's effectiveness. The N-Gain score, calculated by measuring the difference between the post-test and pretest scores, yielded an average value of 0.67, reflecting a 67.89% improvement in learning from the baseline condition. The N-Gain scores ranged from 0.37 to 1.00, indicating varying degrees of learning improvement across the sample. The standard deviation of the N-Gain score was 0.13, suggesting relatively low variability in the scores. The average N-Gain percentage was 67.89%, indicating a significant learning improvement of 67.89%. The N-Gain percentage ranged from 36.67% to 100.00%, reflecting variation in the extent of learning enhancement. The standard deviation of the N-Gain percentage, at 13.71, highlights a considerable degree of variability.

Overall, the data indicates that the N-Gain values are meaningful, demonstrating significant learning improvement, with the average N-Gain score exceeding 0.50 (or 50%) and the average N-Gain percentage reaching 67.89%. However, some variability in the level of learning improvement was observed among the analyzed samples. The GeoGebra-based area and perimeter teaching module effectively enhances learning outcomes, particularly in improving critical thinking skills among students in class VII D. Nonetheless, there remains potential for further refinement to maximize learning gains.

### *Discussion*

The results of this study offer a comprehensive analysis of the effectiveness of a GeoGebra-based teaching module designed for seventh-grade students learning about area and perimeter. In direct response to the research question regarding the module's impact on critical thinking, the findings demonstrate a significant improvement in students' understanding and critical thinking skills. This improvement is evident in the high practicality scores, consistently exceeding 80.00%, highlighting the module's ease of use, time efficiency, and flexibility in engaging students. This suggests that the module holds strong potential for broader adoption and effective integration within the context of seventh-grade mathematics classrooms. Furthermore, the positive outcomes from the implementation trials and paired sample t-tests offer compelling evidence that the GeoGebra-based module effectively conveys complex mathematical concepts and contributes to enhancing critical thinking skills, as targeted by the study. These promising results suggest integrating technology into mathematics education can substantially enhance learning outcomes.

The paired sample t-test results, which show a significant increase in mean scores from 65.06 in the pretest to 88.62 in the post-test, underscore the effectiveness of the GeoGebra-based intervention. The statistically significant p-values ($p < .001$) confirm that these improvements are not due to chance, providing robust evidence that the GeoGebra-based module significantly enhances students' understanding of area and perimeter concepts. These findings align with those of Erlita et al. (2022), who reported increased student engagement and interest when using GeoGebra for quadrilateral studies. However, while Erlita et al. primarily focused on engagement and interest, our study extends these findings by quantitatively demonstrating improvements in critical thinking and comprehension, thereby addressing a gap in the literature regarding the cognitive benefits of using GeoGebra in mathematics education.

Despite the promising results, the study also identifies areas for further research. The relatively lower scores in identifying the characteristics of quadrilaterals suggest a need for modules that offer a deeper exploration of geometric properties. Future modules could incorporate more interactive elements that enable students to dynamically manipulate and observe the properties of various quadrilaterals, thereby enhancing their understanding. Expanding the study to include a broader demographic would allow for greater generalization of the findings. This research was limited to Madrasah Tsanawiyah Nasional 2 Mojokerto; extending it to a variety of educational settings could provide more comprehensive insights. Moreover, longitudinal studies could help assess the long-term retention of knowledge and skills acquired through GeoGebra-based modules.

Future research could also benefit from the inclusion of a control group to strengthen the causal inferences of the study. Although the paired sample t-test is a robust statistical method, having a comparison group that does not use the GeoGebra-based module would provide more precise insights into the specific contributions of the module, as opposed to other potential influencing factors. This would enhance the conclusions' validity and offer a more nuanced understanding of the module's effectiveness in improving students' mathematical abilities.

## CONCLUSION

**Fundamental Finding:** Developing GeoGebra-based teaching modules for area and perimeter topics in seventh-grade mathematics, guided by the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, has revealed crucial insights into

educational resource needs and effectiveness. An object analysis uncovered an average student understanding rate of 79.125% for these topics, while a needs analysis exposed a significant resource gap, with only 12% availability of such modules in school libraries. The resulting 30-page A4 book addresses this deficit, comprising instructional material, worksheets, and GeoGebra applets with embedded critical thinking questions. Expert validation yielded high scores, confirming the module's suitability. Practical trials demonstrated the module's efficacy in enhancing students' critical thinking skills, as evidenced by a substantial N-Gain score of 0.6789. These findings underscore the potential of technology-integrated, specifically designed educational resources to address content understanding and higher-order thinking skills in mathematics education. **Implication:** The development and implementation of GeoGebra-based teaching modules show promise for enhancing mathematics education. Improving students' critical thinking skills suggests that integrating technology and interactive tools like GeoGebra may improve learning outcomes. This approach addresses gaps in available resources and offers a potentially effective method for teaching complex mathematical concepts. The positive reception from students and teachers indicates that such modules could be valuable additions to various educational settings. While further research is needed to confirm long-term effects and broader applicability, this study provides a foundation for exploring how technology-enhanced modules might be used to support mathematics education more widely. **Limitation:** The study is limited by its scope and sample size. Conducted within the specific educational context of Madrasah Tsanawiyah Nasional 2 Mojokerto, the research involved limited participants, which may not fully capture the module's potential across different student populations or educational environments. Additionally, the study's focus was restricted to the area and perimeter of quadrilaterals, which may only partially represent the broader applicability of GeoGebra-based modules across other mathematical topics. **Future Research:** Future research should explore the application of GeoGebra-based teaching modules across a broader range of mathematical topics and educational contexts. Expanding the sample size and including diverse student populations would provide a more comprehensive understanding of the module's effectiveness. Additionally, longitudinal studies are needed to examine the long-term impact of these modules on students' critical thinking skills and overall academic performance. Further investigation into integrating GeoGebra with other technological tools and teaching methods could also enhance the practicality and effectiveness of these educational resources, potentially leading to more innovative and impactful approaches in mathematics education.

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