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ENHANCING CRITICAL THINKING IN GEOMETRY WITH GEOGEBRA: A FOCUS ON CUBES AND CUBOIDS

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Abstract

This study examined the improvement of geometry learning with the use of GeoGebra, focusing on the aspect of students' critical thinking skills. The method used was quantitative experimental research involving 59 eighth-grade students from a public middle school in Majalengka, Indonesia, who participated in two research groups: 29 students in the GeoGebra class and 30 students in the class without GeoGebra in learning cube and cuboid materials. We used a pre-post test to collect data, and for data analysis, we used a t-test to examine the differences in ability between the two groups and a post hoc test as a follow-up. The research results showed that there was a difference in the average critical thinking skills of the two groups, and learning with GeoGebra could improve the five aspects of critical thinking skills. The improvement occurred because geometry encouraged students to think critically through assumptions, predictions, and hypotheses in problem-solving through visualization. This research opened opportunities for future studies to explore the long-term effects of GeoGebra on critical thinking, its application in other mathematical topics, or comparisons with other educational technologies.

Keywords: Critical thinking skill, Cube, Cuboid, GeoGebra, Geometry.

1. Introduction

Critical thinking skills are needed as a skill to solve mathematical problems, one of which is on geometry material [1-5]. Learning geometry helps students enhance their abilities in critical thinking, visualization, intuition, problem-solving, making conjectures, deductive reasoning, constructing logical arguments, and developing proofs [6]. Students face challenges in studying geometry and many struggle to grasp the concept and required knowledge [7]. GeoGebra can combine dynamic visualization of geometry and the outcomes of mathematical computations simultaneously [8].

This Software is widely utilized as a tool to construct, demonstrate, or visualize abstract problems in mathematics that cannot be resolved manually, especially in the field of geometry. Geometry applies to the day-to-day activities of different fields and relevant employment skills [9]. Through GeoGebra, students can analyse problems and improve their critical thinking skills in geometry learning. Table 1 shows several studies on the use of GeoGebra to enhance critical thinking skills in geometry.

However, these studies have not thoroughly analyzed how GeoGebra specifically influences the various aspects or indicators of critical thinking skills. Most focus solely on its general impact on students' critical thinking abilities. Furthermore, preliminary research conducted with secondary school students in Majalengka, Indonesia, reveals their low critical thinking skills remained [10].

This study examined the improvement of geometry learning with the use of GeoGebra, focusing on aspects of students' critical thinking skills. This study used an experimental method with testing on pre- and post-test data from critical thinking skills questions on geometry material. Novelties were: (i) in-depth analysis of critical thinking aspects, definitely elementary clarification, basic support, inferences, advanced clarification, and strategies and tactics through the use of GeoGebra; (ii) in-depth analysis of the concept of cubes and cuboids with GeoGebra; and (iii) analysis of geometry that focuses on critical thinking aspects.

Table 1. Previous research on the use of GeoGebra to improve critical thinking skills in geometry.

No.	Title	Ref.
1.	Enhancing students' higher-order thinking skills (HOTS) through an inductive reasoning strategy using GeoGebra	[11]
2.	The use of GeoGebra software in improving students' mathematical abilities in learning geometry	[12]
3.	Students' mathematical critical thinking using GeoGebra software based on adversity quotient	[13]
4.	Improving student's critical thinking skill in mathematics through GeoGebra-based flipped learning during pandemic covid-19: An experimental study	[14]
5.	Improving student's critical thinking ability through guided discovery learning methods assisted by GeoGebra	[15]

2. Literature Review

Figure 1 shows the relationship between geometry and GeoGebra and their influence on improving students' critical thinking. GeoGebra provides a wide-

ranging online help feature, making points, lines, graphs, polygons, translation, and other functions more easily and accurately [16]. This software stands out from most mathematics programs because it places a greater emphasis on geometry [17, 18]. Geometry is the study of the relationships between points, lines, surfaces, angles, and shapes [12]. Geometry is a crucial branch of mathematics due to its connection with everyday life situations, especially to solve human and natural problems like everyday life problems [19]. An example is to specify quantities, measure figures, land, and earth, and make maps [20]. Visualization and interactivity in learning geometry using GeoGebra encourages students to think critically in solving problems such as elementary clarification, basic support, inference, advanced clarification, strategies, and tactics [16, 21].

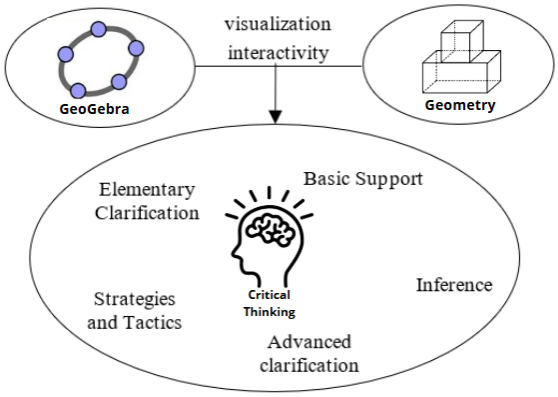

Fig. 1. The relationship between GeoGebra, geometry, and critical thinking.

21st-century learning, other than implementing HOTS in mathematics, needs an educational resource aid based on technology, such as GeoGebra, the dynamic geometrical software [11]. Through GeoGebra, Geometry concepts and ideas of geometry have been introduced to students since their study at the elementary school level, for example, the introduction of line, plane, and space [6]. This article focuses on the geometry of cubes and cuboids as the material studied through GeoGebra. Critical thinking is the act of solving problems critically to increase knowledge [22]. Students can use their critical thinking to be rational and precise in determining solutions using effective analysis, synthesis, and evaluation processes with GeoGebra [23, 24]. Developing critical thinking skills, including problem-solving, questioning, and analysis, is a crucial aspect of mathematics education [25-27].

3.Method

We used a quasi-experimental design with a pre and post-test in this research. The experimental class used learning with GeoGebra, and the control class used learning without GeoGebra. The participants were 59 eighth-grade students from three different classes at a public middle school in Majalengka, Indonesia. Twenty-nine students were in the first experimental group, and thirty students participated in the control group. The research analysis used the T-test and post hoc test, which were continued to find out which model had the highest influence on students' critical thinking abilities.

4. Results and Discussion

The results of the initial analysis of both data showed that both data were normally distributed. To determine whether there was a difference in the average critical thinking ability between groups after learning, a parametric t-test was conducted. The t-test showed a sig.<0.05, meaning that there was a significant difference in the average critical thinking ability of students from the two research groups. Detailed information regarding t-test analysis is reported elsewhere [28, 29]. We analysed the difference in critical thinking ability between groups on critical thinking aspects using the Kruskal-Wallis test. The test results showed that the highest mean rank of critical thinking skills in each indicator was produced by the class with GeoGebra compared to the class without GeoGebra, namely MR = 59.90 for elementary clarification, MR = 67.38 for basic support, MR = 61.19 for inferences, MR = 62.09 for advanced clarification, and MR = 64.95 for strategies and tactics. These results illustrated that the GeoGebra group obtained the highest average score on each indicator of critical thinking ability. The Kruskal-Wallis test results also showed Sig. <0.05 for all indicators in both research groups. These results indicated that the five critical thinking indicators were significantly different in each research group.

Figure 2 shows how GeoGebra presented features that could facilitate students in examining the concept of elements and nets of cubes and cuboids. This activity supported the development of critical thinking skills in the elementary clarification and basic support aspects. Students could recognize elements such as corner points, side planes, diagonal planes, diagonal planes, and the shape of the nets of cubes and cuboids through observations on GeoGebra. Understanding this concept was the basis for providing general explanations and the foundation for supporting problem-solving. GeoGebra also facilitated students in calculating surface area and volume simply and easily as part of the advanced clarification aspect. GeoGebra encouraged students to explore and understand geometry more clearly, and they could observe geometric shapes from various points of view. Students were able to create models and modify object variables, reflect and rotate objects, and then track changes in the objects' locations and pictures [30]. This situation provided a difference in students' ways of thinking in solving problems between students who studied with GeoGebra and those who did not use GeoGebra.

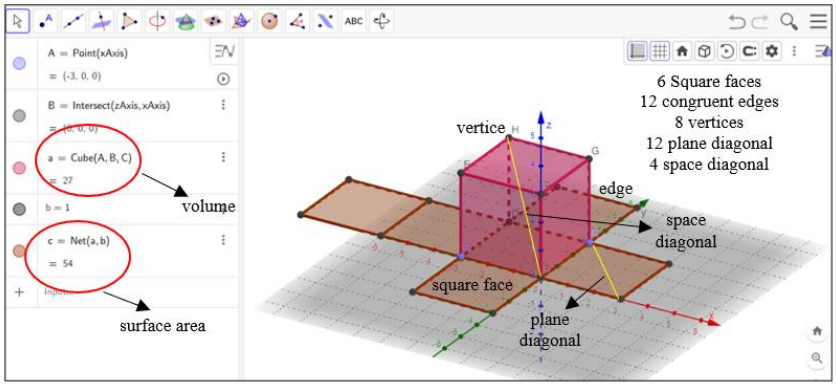

Fig. 2. Analysis of the aspects of elementary clarification, basic support, and advanced clarification using GeoGebra.

Consider the following questions about geometry material.

Question: *Mr. Andrew made a cuboid-shaped frame from the wire. What elements and formulation do Mr. Mamat need to know to make the right size cuboid frame?*

Classroom students without GeoGebra could not answer correctly because of the difficulty in imagining the cuboid frame, while students in the class with GeoGebra, through GeoGebra, understood the shape of the cuboid in real terms. By visualizing the cuboid through GeoGebra, they were able to understand mathematical concepts more deeply.

Figure 3 shows that GeoGebra helped students to make assumptions, predictions, and hypotheses. Students could also clearly relate their existing knowledge to the new one through visualization [11]. Through visualization, students understood the problem, identified, and analysed answers, and provided appropriate conclusions as aspects of inference strategies and tactics. Students could rely on the results found on GeoGebra software to draw their conclusions. Students identified the required elements based on the visualization of the image and concluded the required formula through analysis of the GeoGebra image. A cuboid had three main dimensions: length (p), width (l), and height (t). The frame of the cuboid consisted of 4 edges with p, 4 edges with l, and 4 edges with t. Therefore, the total length of the frame of the rectangular prism could be calculated using the formula: $4 \times (p + l + t)$. Based on the forecast results generated by the GeoGebra software, learners relied on that, mobilizing their available knowledge and experience to find the solution themselves [31]. The use of GeoGebra lets students make mathematical generalizations more effectively [32]. Geometry learning has contributed to helping students develop visualization and critical thinking skills [6, 33]. Critical thinking skills were the foundation for solving math problems. As a result, students' academic achievement in mathematics material increased. This finding was also reinforced by another study that found learning using GeoGebra could improve student academic achievement [34]. Utilizing GeoGebra in educational activities significantly enhanced students' performance and independence, structured teaching guidance, and simplified the learning process.

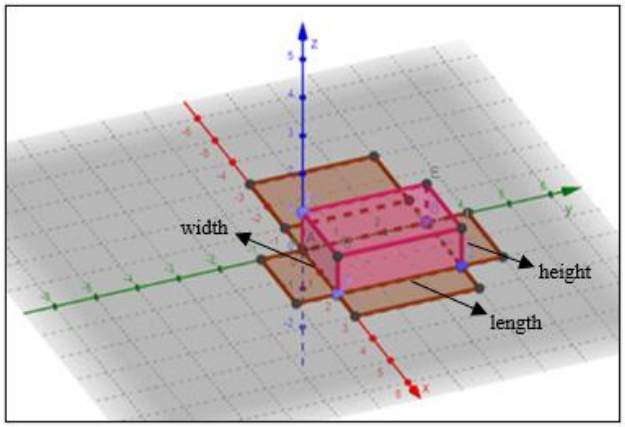

Fig. 3. Analysis of the aspects of inferences and strategies tactics using GeoGebra.

5. Conclusion

The results of the study revealed that GeoGebra was successful in improving critical thinking abilities in geometry, especially regarding cubes and cuboids. It has helped improve various critical thinking aspects, including elementary clarification, basic support, inferences, advanced clarification, and strategies and tactics. By using GeoGebra, students were able to easily analyse geometric elements through visualizations, identify issues, process data, select appropriate strategies for problem-solving, and draw conclusions based on the data.

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