Using of GeoGebra to Improve Mathematical Reasoning with the Problem-Solving Method

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Abstract. This research aims to look at the use of GeoGebra in solving geometric problems in life, especially to improve the mathematical reasoning abilities of high school students. This quasi-experimental research with static comparison design involved 82 students from high Prior Mathematical Knowledge (PMK), moderate Prior Mathematical Knowledge (PMK), and low Prior Mathematical Knowledge (PMK). The instrument used in this research include the Prior Mathematical Knowledge test. Data were analyzed by t-test. The result of the research shows that at high and low Prior Mathematical Knowledge(PMK) levels there were no significant differences while at the moderate Prior Mathematical Knowlege (PMK) level there were differences in students‘ mathematical reasoning abilities using GeoGebra in problem-solving learning.

Keywords: GeoGebra, mathematical reasoning, problem-solving method.

1 Introduction

Mathematical reasoning ability becomes an important part of learning mathematics at every level of education. The reasoning is required to strengthen basic concepts and train students' thinking processes and are the basis of mathematical understanding [1]. On the other hand, based on the Trends Report in the International Mathematics and Science Study (TIMSS) in 2011, Indonesian student‘s reasoning scores were 388. These results indicate that Indonesian students' reasoning abilities are still relatively low compared to most countries participating in TIMSS 2011 [2]. One branch of mathematics that require reasoning ability is geometry.In learning geometry, students often struggle when they have to imagine abstract objects. Many students also have difficulty in solving problems at the final calculation level by connecting the previous concepts [3]. This shows that students' reasoning abilities in geometry material tend to be weak.

To improve students' mathematical reasoning abilities, especially in geometry concepts, changes and innovations are needed in learning geometry in the classroom.Many studies in mathematics learning prove that the use of geometry software can help to learn geometry in the classroom, especially to analyze and assist student difficulties in proof [4]. One software that can be used is GeoGebra. GeoGebra is a dynamic mathematical software that combines arithmetic, geometry, algebra, and calculus for all levels of education. The use of GeoGebra can help students see abstract concepts, make connections, and discover mathematical concepts [5].The use of GeoGebra in learning mathematics in the classroom should be integrated with the appropriate learning methods. According to Majerek, GeoGebra can be used in learning that is oriented to activity and problems [6]. One learning method that can be

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used is a problem-solving method. Through problem-solving learning, students can acquire ways of thinking, habits of persistence and curiosity and confidence in unfamiliar situations [7].Based on the description above, the author was encouraged to conduct research that focused on the use of GeoGebra to improve students' mathematical reasoning through problem-solving methods.

2 Mathematical Reasoning, GeoGebra, and Problem Solving

2.1 Mathematical Reasoning

The definition of mathematical reasoning cannot be separated from the definition of reasoning itself. The reasoning is a process for analyzing problems, finding solutions, developing conjectures, and for testing the correctness of conjectures [8]. The reasoning is part of the thinking that goes beyond the level of recall and includes basic thinking, critical thinking, and creative thinking [9]. The reasoning is the process of concluding based on principles and facts where someone draws new conclusions or evaluates known conclusions.Reasoning about mathematical objects is referred to mathematical reasoning. Mathematical reasoning is the basic ability required to understand mathematical concepts, use flexible mathematical ideas and procedures, and to construct mathematical knowledge [10].

2.2 Software GeoGebra

GeoGebra is a dynamic mathematical software that combines Geometry, Algebra, and Calculus [11]. According to [11] [12], this program can be used to improve students' understanding of concepts that have been learned as well as a means to introduce or construct new concepts. GeoGebra software is very useful for teachers and students. For teachers, GeoGebra offers effective opportunities to create interactive learning media that allow students to explore various mathematical concepts. It can also help teachers improve students' understanding of mathematical concepts and procedures because this software offers mathematical functions such as symbols, graphics, and more [13] [14]. GeoGebra facilitates interactive exploration to encourage students to be actively involved in the learning process [15]. Teaching mathematics becomes explorative where students can see directly and directly the relationship between analytic representation and visual, mathematical concepts.

2.3 Problem Solving Method

Problem-solving is a teaching method used by the teacher in the learning process which includes the ability to search for information, analyze situations, and identify problems with the aim of producing alternatives so that they can take action to reach the goal [16]. According to Polya in Silver, Mathematical problem solving is a way to solve mathematical problems using mathematical reasoning (mathematical concepts) that have been mastered before [17].Problem-solving is an activity where students are faced with conditions that do not have clear or routine solutions, so they must act according to the situation and involve various mental processes and behaviors to get solutions. [18] Pólya lays out a problem-solving heuristic thatrelies heavily on a repertoire of experience. He summarizes the four-stepprocess

of his heuristic as follows: Understanding the Problem, Devising a Plan, Carrying Out the Plan, and Looking Back[19]

3 Methodology

The design used in this quasi-experimental study was a nonequivalent control group design, the treatment involving the experimental and control groups was given the initial test (pretest) and the final test (posttest) given the Previous Mathematics Knowledge test. The subjects in this study were grade XII students of State High Schools in Central Jakarta, Indonesia. Because students at that age are able to follow the learning given by the teacher well, so the level of thinking has begun to shift from concrete to abstract, to identify students' initial mathematical abilities before participating in computer laboratory learning activities and initial mathematical abilities before research. The experimental class consisted of 41 students, 8 students in the high Prior Mathematical Knowledge (PMK) category, 25 students in the moderate Prior Mathematical Knowledge (PMK) category and 8 low Prior Mathematical Knowledge categories. The control class consisted of 41 students, 8 students in the high prior mathematical Knowledge (PMK) category, 26 students in the moderate Prior Mathematical Knowledge (PMK) category and 7 students in the low Prior Mathematical Knowledge (PMK) category. The datasets of this research is accestable at: (https://mfr.osf.io/render?url=https://osf.io/6akgr/?action=download%26mode=render).

3.1 Mathematical Reasoning Test

The Mathematical Reasoning Ability (MRA) instrument in this study has gone through the validity and reliability tests of experts and students. the validity of the Mathematical Reasoning Ability (MRA) instrument shows a valid statement with a reliability coefficient of 0.771. The MRA test is used to measure students' initial skills before being treated using Geogebra + Problem Solving learning and ordinary learning. The Mathematical Reasoning Ability test consists of mathematical material tests related to the material used by researchers in this study. Based on table 1, a grouping of high Prior Mathematical Knowledge (PMK) categories, moderate Prior Mathematical Knowledge (PMK) and low Prior Mathematical knowledge (PMK) are as follows:

Table 1. Student Grouping Criteria

Criteria	Student group
Prior Mathematical Knowledge $\leq$ 72.25	Low
72.25 $\leq$ Prior Mathematical Knowledge<88.33	Moderate
Prior Mathematical Knowledge< 88.33	High

Indicators of mathematical reasoning abilities used in this research include:

Table 2. Mathematical Reasoning Ability Indicators

Variables	Mathematical Reasoning Aspects	Mathematical Reasoning Indicators
1	2	3
Mathematical Reasoning	*Transductive*	Integrate some knowledge and make connections between ideas for explanation of models, facts, properties, relationships or patterns
	Analogy	Analyze situations mathematically through a process of analogy by paying attention to similarities and differences
	Generalization	Perform a generalization process to look at causal relationships, to make decisions, and to test hypotheses and scientific investigations

3.2 Techniques of Data Analysis

Data is processed from the student posttest results towards the achievement of student MRA. The results of these achievements are processed by descriptive and inferential statistical analysis. The statistical analysis used was t-test and Mann-Whitney test with a significant 0.05. The population in this study were all students of class XII in one of the State High Schools in Jakarta. Samples are a subset of the population whose characteristics are really investigated. Data provided by samples can be used for estimate the overall data on the population. Characteristics of class XII in one The State High School in Jakarta is receiving the same learning material and they learn math with the same amount. The sample from this study is two classes that selected by Cluster Random Sampling techniques. Each one is chosen randomly to be determined to be experimental class and control class.

4 Result and Discussion

The descriptive statistics ofstudents' mathematical reasoning abilities based on the Prior Mathematical Knowledge (PMK) category are as follows:

Table 3. Descriptive Statistics of Reasoning Ability Based on Prior Mathematical Knowledge

PMK	Ideal Score	GBG+PS Class					Conventional Class				
		N	$x_{\min}$	x_{maks}	$\bar{x}$	S_d	N	$x_{\min}$	x_{maks}	$\bar{x}$	S_d
High	24	9	0.38	0.73	0.58	0.15	8	0.27	0.75	0.61	0.16
Moderate		24	0.21	0.86	0.47	0.03	26	0.19	0.19	0.54	0.14
Low		8	0.19	0.73	0.42	0.17	7	0.00	0.00	0.22	0.27

Table 3 shows that the achievement of the average mathematical reasoning ability of students who get gbg + ps learning is better than students who get conventional learning. the results of student's reasoning ability based on high Prior Mathematical Knowledge (PMK) categories, moderate Prior Mathematical Knowledge (PMK) and low Prior Mathematical Knowledge (PMK) must meet the difference test requirements between students who worked under Geogebra + Problem Solving learning and students who worked under regular learning. From normality test, the results shows that the data are normal not homogenous for group of low PMK.Tables 4 shows the result of t-test with a significant 0.05 using t-test and t'-test.

The hypothesis are: there is no significant difference in the improvement of mathematical reasoning abilities between students who get geogebra assisted geometry learning and students who obtain conventional mathematics learning in terms of the overall students. To test the statistical hypothesis is formulated as follows:

Table 4. Test Differences of Students' Mathematical Reasoning Abilities

PMK Level	t	df	Sig.	Conclusion
High	-0.97	14	0.17	Ho Accepted
Moderate	1.87	50	0.03	Ho Rejected
Low	1.76	13	0.05	Ho Accepted

H_0: Means of two group is same

Based on table 4, it can be concluded that the ability of mathematical reasoning based on Prior Mathematical Knowledge (PMK) is obtained as follows, 1) At high and low PMK levels there is no significant difference in mathematical reasoning ability between students who get learning with geogebra and problem-solving method and students who get conventional mathematics learning in terms of high, medium and low groups; 2) At the PMK level there are differences in mathematical reasoning abilities of students who get learning with geogebra and problem-solving method is better than students who get conventional mathematics learning in terms of high, medium and low groups.

The following tables presentes the results of Geogebra + Problem Solving class students' work with conventional class students on 3-dimensional geometry problems:

"Borobudur Temple is one of Indonesia's valuable and famous cultural assets. Maybe, this tourism destination is not something new for you. But do you know the size of the temple? Apparently, the temple building area is 123m x 123m with a building height of 34.5 m and has 1460 reliefs, 504 Archa Buddha, and 72 stupas. Borobudur Temple has 10 levels (symbolizing the ten levels of Bodhisattva that must be passed to reach perfection to become Buddha) consisting of 6 levels in a square, 3 round circular shapes, and a main stupa as a peak. What is the angle at the top of the temple?"

Answer:

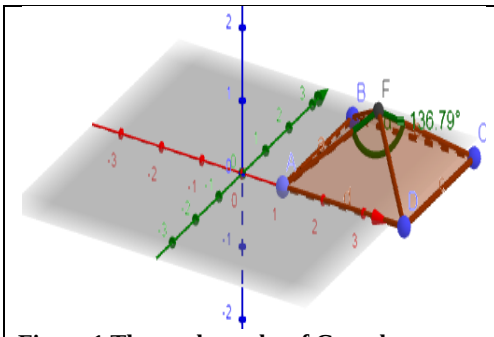

Figure 1.The work results of Geogebra + Problem Solving Class student

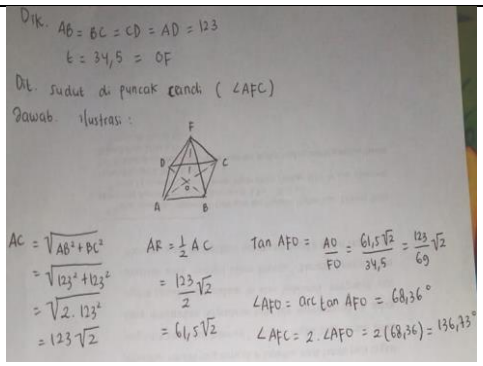

Figure 2. The work results of conventional class student

Students of the GBG+PS class and conventional classes were both asked to solve problem 1 where students were asked to determine the angle at the top of the Borobudur temple. There is an equation in the final answer given if the number is rounded to the closest unit. There are also some differences in ways to solve problems. Based on figure 1. it can be seen that students can easily determine the size of the angle at the top of the temple, while based on figure 2. it can be seen that students need a long stage to find a solution to the problem given. Students also need help with a calculator because this problem involves quite complex numbers. The temple illustrations drawn by the GBG-PS class students are clearly illustrated while the temple illustrations drawn by conventional class students are less clear. This shows that the use of GeoGebra can make it easier for teachers and students to solve 3-dimensional geometry problems in real life.

5 Conclusion

The results showed that at high and low Prior Mathematical Knowledge (PMK) levels there were no significant differences while at the moderate Prior Mathematical Knowledge (PMK) level there were differences in mathematical reasoning abilities of students using GeoGebra in problem-solving learning so it could be concluded that using of GeoGebra could be used to improve students' mathematical reasoning abilities especially students with Prior Mathematical Knowledge (PMK) is being this research also shows that GeoGebra can be used to solve Three-dimensional geometry problems that exist in the real world.

For further research, GeoGebra can be used to improve other mathematical abilities and be applied with different learning strategies.The use of GeoGebra is recommended for use by teachers in geometry learning especially in three-dimensional material to improve learning outcomes of students who have a value of initial reasoning ability. In addition, related agencies can hold training on using GeoGebra for math teachers so that the benefits of using GeoGebra can be felt by many students.

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