

IMPLEMENTATION OF SPACE GEOMETRY LEARNING USING GEOGEBRA TO IMPROVE PROBLEM SOLVING SKILLS

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Abstract:

Prospective mathematics teachers must be equipped with problem solving skills because it has a very important place in the mathematics curriculum. The purpose of this research is to get an overview of improving the problem solving skills of prospective mathematics teachers by implementing GeoGebra on space geometry learning. The research was conducted in Study Program of Mathematics Education, Tidar University in the second semester students. This research uses quasi-experimental method, with nonequivalent control group pretest-posttest design using two groups, namely experimental group consisting of 36 students got GeoGebra-based space geometry learning and control group consisting of 35 students got conventional space geometry learning. Research instruments in the form of observation sheets and test instruments in the form of pretest and posttest to measure achievements of problem solving skills improvement. The data obtained is then processed and analyzed by calculating the percentage of learning implementation and calculating the average normalized gain score (N-Gain). The results showed that GeoGebra-based Space Geometry learning can improve problem solving skills. In the experimental group, problem solving skills were improved in high category, while in the control group the improvement of problem solving skills in moderate category.

Keywords: Space Geometry, GeoGebra, Problem Solving Skills

IMPLEMENTASI PEMBELAJARAN GEOMETRI RUANG BERBASIS GEOGEBRA UNTUK MENINGKATKAN KETERAMPILAN PEMECAHAN MASALAH

Abstrak:

Calon guru matematika harus dibekali dengan keterampilan pemecahan masalah karena memiliki posisi yang sangat penting dari kurikulum matematika. Tujuan penelitian ini adalah mendapatkan gambaran peningkatan keterampilan pemecahan masalah mahasiswa calon guru matematika dengan mengimplementasikan GeoGebra pada pembelajaran geometri ruang. Penelitian dilaksanakan di Program Studi Pendidikan Matematika Universitas Tidar pada mahasiswa semester II. Penelitian ini menggunakan metode quasi experiment, dengan desain penelitian nonequivalent control group pretest-posttest menggunakan dua kelompok yaitu kelompok eksperimen yang terdiri dari 36 mahasiswa mendapat pembelajaran geometri ruang

berbasis GeoGebra dan kelompok kontrol yang terdiri dari 35 mahasiswa mendapat pembelajaran geometri ruang secara konvensional. Instrumen penelitian berupa lembar observasi dan instrumen tes berupa pretest dan posttest untuk mengukur capaian peningkatan keterampilan pemecahan masalah. Data yang diperoleh kemudian diolah dan dianalisis dengan menghitung persentase keterlaksanaan pembelajaran dan menghitung rata-rata skor gain yang dinormalisasi (N-Gain). Hasil penelitian menunjukkan bahwa pembelajaran geometri ruang berbasis GeoGebra dapat meningkatkan keterampilan pemecahan masalah. Di kelompok eksperimen, peningkatan keterampilan pemecahan masalah dalam kategori tinggi, sedangkan pada kelompok kontrol peningkatan keterampilan pemecahan masalah dalam kategori sedang.

Kata Kunci: Geometri Ruang, GeoGebra, Keterampilan Pemecahan Masalah

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INTRODUCTION

To become prospective mathematics teachers, students are required to be able to review the concepts that they have obtained during learning to their students in the school later. Therefore, prospective mathematics teachers should be provided with problem solving skills which is one of the must-have skills. This is because problem solving skills can make us think logically, critically, and creatively. Problem solving is recognized as a very important life skill because it involves a variety of processes including analyzing, interpreting, reasoning, predicting, evaluating, and reflecting (Anderson, 2009).

The problem solving skills steps of one of them popularized by Polya (2004) consists of four steps, namely: 1) understanding the problem, 2) devising a plan, 3) implementing the plan, and (4) looking back at the original answer. The National Council of Teachers of Mathematics explained that mathematics problem solving skills need to be developed in mathematics learning (NCTM, 2000). Students should be allowed to implement and adopt the right strategies to solve problems. Therefore, each lesson must be designed to provide students with problem solving skills.

Problem solving skills also have an important place for the primary purpose of a curriculum (Ozturk & Guven, 2016). In the curriculum of the

Mathematics Education study program at Tidar University, students are equipped with one of the mandatory courses that are space geometry. This course is very important for students of prospective mathematics teachers because the material is widely found in the curriculum of mathematics subjects taught at the elementary and secondary school levels. Therefore, the student must possess and develop his problem solving skills, considering in his or her job later when becoming a teacher in teaching students to solve mathematics problems. The participation of mathematics teachers in the process of technology integration has been emphasized by encouraging most of their teaching practices and making students learn better in the classroom (Cuban, Kirkpatrick, & Peck, 2001).

The importance of mathematics problem solving skills on the concept of space geometry for students of prospective mathematics teachers is contrary to the conditions that exist in the field. The results showed that space geometry is a difficult course. Hanafi (2017) shows that geometry learning difficulties are in the high category resulting from a less effective learning process in students of the mathematics education study program in 2009. The same findings were also supported by researchers in initial observations to several prospective mathematics teachers in second-semester who had already received space geometry courses. Preliminary observations showed that students' problem solving skills were still low, with the fact that more than 60% of students scored less than 70 with a maximum score of 100. The lack of problem solving skills is caused by the learning process. This is in accordance with the results of interviews with some students of the even semester in 2018/2019 among others: 1) the learning process using more lecture methods, and 2) the learning process has not used technology that is able to provide visualization of materials and concepts.

Space geometry is one of the courses offered in the second semester in the Mathematics Education Study Program, Tidar University. This course is the development and continuation of plane geometry courses. According to the curriculum of the Mathematics Education Study Program, this course contains mathematics objects (points, lines, planes) in space, relationships between geometric objects, planes, limas, prisms, cones, cylinder, spheres, measurements involving objects and shapes of space geometry, space image construction techniques and relationships between objects of space geometry. This standard of learning competency is that students are able to understand and have good space responsiveness, master concepts, and be able to solve

problems related to building space. In its implementation, there are still many students who solve problems of space geometry learning algorithmically and procedurally (Susilo, Sutarto, & Mubarok, 2015).

Abramovich (2013) defines GeoGebra as a free online software application for the study of geometry, algebra, and calculus at different grade and teaching levels. GeoGebra is designed to combine dynamic geometry software features (Cabri, Geometer Sketchpad) and computer algebra systems (Derive, Maple) in a single, integrated, and easy-to-use system for teaching and learning mathematics (Hohenwarter, Jarvis, & Lavicza, 2009). GeoGebra is based on scientific mathematics criteria. GeoGebra has several advantages, including exploring and manipulating various geometric shapes in an activity that students can do by drawing sketches (Stols & Kriek, 2011). GeoGebra enables teachers to create interactive learning to encourage discovery learning for students while interacting visually on geometry topics. This is a powerful teaching tool for mathematics teachers to provide geometry concepts.

Many studies have discussed GeoGebra, but no one has yet analyzed GeoGebra's relationship with mathematics problem solving skills. Several studies have shown that GeoGebra is able to have a positive impact on students' understanding of concepts (Kurniasih, Wiyanti, & Zahid, 2018; Lestari, 2018; Mudaly & Fletcher, 2019). Likewise, some studies have also tried to design space geometry learning, but no one has yet used GeoGebra to apply it to the course (Untarti & Kusuma, 2018; Wahyuni & Rahmadhani, 2019).

Based on the above description, a research is needed on the implementation of GeoGebra-based space geometry lectures to improve problem solving skills. The purpose of this research is to get an overview of improving the problem solving skills of prospective mathematics teachers by implementing GeoGebra in space geometry lectures. This research is considered very important to be carried out in order to meet the demands of lecture standards in LPTK (*Lembaga Pendidikan Tenaga Kependidikan*) to apply learning technology to students of prospective mathematics teacher as well as to facilitate prospective teachers in improving mathematical problem solving skills.

METHODS

This research used a quasi-experiment, with a research design is a nonequivalent control group pretest-posttest. The study used two groups, one as an experimental group that received GeoGebra-based space geometry

learning and another group as a control group that got space geometry learning without using GeoGebra. The topics in space geometry discuss cone, cylinder, and sphere. The experiments were conducted 6 times. The design of the research is shown in table 1.

Table 1. Research Design

Experiment	T ₁	X	T ₂
Control	T ₁	C	T ₂

Description:

- T₁ = pretest of problem solving skills
- X = application of GeoGebra-based space geometry learning
- C = application of conventional method in space geometry learning
- T₂ = posttest of problem solving skills

The research was conducted Mathematics Education Study Program at Tidar University in the second semester of space geometry learning. The independent variable in this study is GeoGebra-based space geometry learning. The dependent variable is problem solving skill. The instruments employed in this study are tests twice and the observation sheet. Test and observation indicators refer to the problem solving skills indicator reported in table 2.

Table 2. Description of Aspects and Indicators of Problem Solving Skills

Aspects	Indicators	Code
Understanding the problem	1. Identifying what is known	U1
	2. Determine the asked	U2
Devising a plan	1. Create a sketch describing the problem	D1
	2. Determine the right equation for problem solving	D2
Implementing the plan	1. Substitute the known into an equation form	I1
	2. Calculate correctly	I2
Looking back	Evaluate answers based on concepts	L1

All instruments have gone through a validation process and are declared valid. There are two validators, they are experts in mathematics and mathematics education. The suggestion of validator is an editorial improvement for the problem so as not to cause multi-interpretation. Data analyzed based on answer sheet when subject solves problem and observation sheet. Test instruments in the form of essays use assessment rubrics to measure students' problem solving skills. The test is done before (pretest) and after (posttest) given treatment.

Analysis of problem solving skills improvement data is based on mean, with steps: 1) scoring pretest and posttest results according to the criteria and rubric scoring created then summing up all scores obtained, 2) calculate the average normalized gain score (N-Gain) to determine the increase in problem solving skills, i.e. with criteria a) low if $g < 0.3$; b) medium if $0.7 > g \geq 0.3$; c) high if $g \geq 0.7$ (Hake, 1999).

RESULTS AND DISCUSSION

The study used two groups, one as an experimental group that received treatment in the form of GeoGebra-based Space Geometry learning and the other group as a control group that received conventional learning treatment. The learning process was performed in both groups through the following stages: 1) pretest, 2) the provision of conventional treatment for the control group, and the learning to use GeoGebra for the experimental group, and 3) posttest.

The results showed that there was an improvement in space geometry problem solving skills after students learned to use GeoGebra. The results of tests of space geometry problem solving skills can be seen in Table 3. Based on Table 3, an average pretest score of 61.4 and an average posttest score of 93.2 on GeoGebra-based space geometry learning was performed on 36 students. Meanwhile, 35 students scored a pretest average score of 63.6 and a posttest average score of 84.6.

Table 3. Comparison of Pretest and Posttest Results in Two Groups

	Experiment				Conventional				
	N	X	$\langle g \rangle$	Category	N	X	$\langle g \rangle$	Category	
Pretest	36	61.4	0.82	High	Pretest	35	63.6	0.57	Medium
Posttest	36	93.2			Posttest	35	84.6		

Based on table 3, it appears that the posttest average score is higher than the pretest of both learning models. These results indicate that there has been an increase in problem solving skills before and after treatment. Gain normality test results showed that there was an increase of 0.82 for GeoGebra-based space geometry learning, and 0.57 for conventional learning. The higher improvement of the gain normality test shows that learning space geometry using GeoGebra contributes better in improving students' problem solving skills towards space geometry.

The percentage of problem solving skills improvement in the experimental group by 83.3% for the high category, 16.7% for the moderate category, and 0% for the low category. In the control group, the increase was 48.6% for the high category, 42.8% in the moderate category, and 8.6% in the low category. Overall, in the experimental group and the control group together, there are improvements in problem solving skills in space geometry learning that can be seen in figure 1.

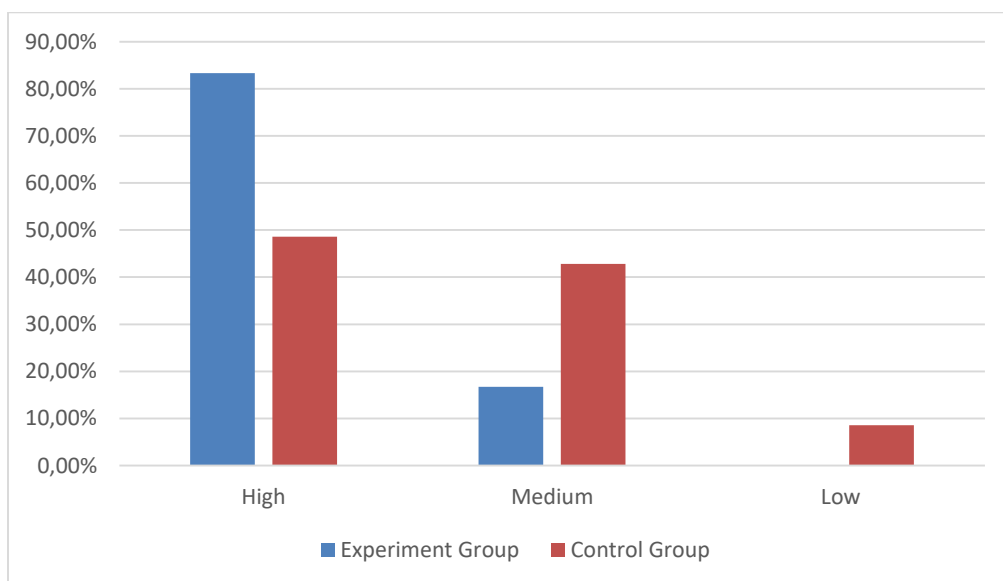


Figure 1. The Percentage of Problem Solving Skills Improvement

Based on the findings of the research, learning space geometry using GeoGebra further improves problem solving skills than conventional learning. Carreira, Jones, Amado, Jacinto, and Nobre (2016) also explained that problem solving is the kind of activity that requires experimentation, exploration, investigation, testing, reflection, and discussion. The results also found that students were able to solve problems very well. Slameto (2010) argues that

problem solving is seen as a process for determining a combination of several rules that can be applied to resolve a new situation. GeoGebra is an effective tool for teaching and learning space geometry in college because it can improve the achievement of learning space geometry on the topic of plane slices on prism (Pamungkas, Rahmawati, & Dinara, 2020).

Figure 2 is one of the students' answers in problem solving by using GeoGebra and problem solving skills indicators. Based on the answer sheet in the experimental group, the solving steps are in accordance with indicators of problem solving skills, including U1, U2, D1, D2, I1, I2, and L1. When compared to the answer sheet of the control group in figure 3, it appears that the student does not show a step indicator of problem solving skills, i.e. only D1, D2, I1.

<p>3. Diketahui suatu bola dengan titik pusat O dan jari-jari 13 cm. Bidang bola itu dipotong oleh dua bidang sejajar K dan M, masing-masing berjarak 5 cm dan 12 cm dari O. Hitunglah volume-volume tembereng bola atas, keratan bola, dan tembereng bola bawah yang terjadi! (Skor 15)</p>		
<p>Jawab</p>		
<p>Sketsa gambar</p>	<p>Hal-hal yang diketahui dari soal</p> <p>Jari-jari bola = 13 cm Jarak bidang K dari O = 5 cm Jarak bidang M dari O = 12 cm</p> <p>Yang ditanya :</p> <p>a. Volume tembereng bola atas.....?</p> <p>b. Volume keratan bola.....?</p> <p>c. Volume tembereng bola bawah.....?</p>	<p>Penyelesaian</p> <p>a. Volume tembereng bola atas</p> <p>Jari-jari tembereng $= \sqrt{13^2 - 5^2}$ $= \sqrt{169 - 25}$ $= \sqrt{144} = 12$ cm</p> <p>Tinggi tembereng $= 13 \text{ cm} - 5 \text{ cm} = 8$ cm</p> <p>Volume tembereng bola atas $= \frac{1}{3} \pi t^2 (3R - t)$ $= \frac{1}{3} \pi 6^2 (3 \cdot 13 - 8)$ $= \frac{1}{3} \pi 54 (39 - 8)$ $= \frac{1}{3} 6^4 \pi \cdot 31$ $= \frac{3864}{3} \text{ cm}^3$</p> <p>b. Volume keratan bola</p> <p>Jari-jari lingkaran atas $= \sqrt{13^2 - 5^2}$ $= \sqrt{169 - 25}$ $= \sqrt{144} = 12$ cm</p>
		<p>Jari-jari lingkaran bawah $= \sqrt{13^2 - 12^2}$ $= \sqrt{169 - 144}$ $= \sqrt{25} = 5$ cm</p> <p>Tinggi keratan bola $= 5 \text{ cm} + 12 \text{ cm} = 17$ cm</p> <p>Volume keratan bola $= \frac{1}{6} \pi t (3r_1^2 + 3r_2^2 + t^2)$ $= \frac{1}{6} \pi \cdot 17 (3 \cdot 12^2 + 3 \cdot 5^2 + 17^2)$ $= \frac{17}{6} \pi (432 + 75 + 289)$ $= \frac{17}{6} \pi (796)$ $= \frac{13532}{6} \pi \text{ cm}^3$ $= 2255,3 \pi \text{ cm}^3$</p> <p>c. Volume tembereng bola bawah</p> <p>Jari-jari lingkaran bawah $= \sqrt{13^2 - 12^2}$ $= \sqrt{169 - 144}$ $= \sqrt{25} = 5$ cm</p> <p>Tinggi tembereng $= 13 \text{ cm} - 12 \text{ cm} = 1$ cm</p> <p>Volume tembereng bawah $= \frac{1}{3} \pi t^2 (3R - t)$ $= \frac{1}{3} \pi 1^2 (3 \cdot 13 - 1)$ $= \frac{1}{3} \pi (39 - 1)$ $= \frac{1}{3} \pi (38)$ $= \frac{38}{3} \pi \text{ cm}^3$</p>

Figure 2. One of the Answer Sheet in the Experimental Group

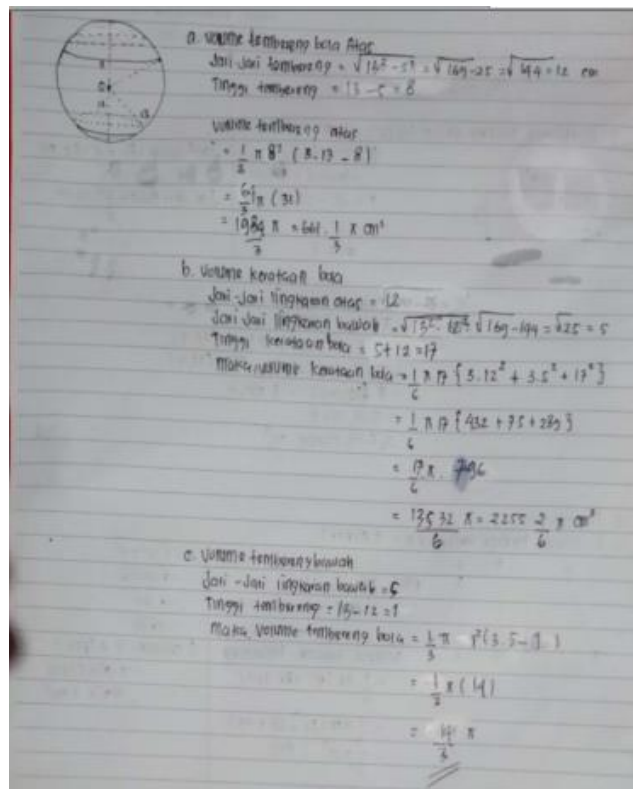


Figure 3. One of the Answer Sheet in the Control Group

GeoGebra can improve students' ability to conceptualize mathematical elements and to improve learning outcomes (Emaikwu, Oche, & Terseer, 2015). Also, GeoGebra is very useful for demonstrating and visualizing mathematical concepts related, primarily to geometric objects (Mahmudi, 2010). This is supported by the results of research conducted by Saha, Ayub, and Tarmizi (2010) conducting research aimed at identifying the impact of GeoGebra use on the teaching of geometry coordinates on a group of secondary school students. The results showed statistically significant differences between the posttest averages of the two groups in the GeoGebra group. The use of GeoGebra has helped prospective mathematics teachers build new knowledge and connect it with previous knowledge, it is useful in improving problem solving skills (Bhagat & Chang, 2015).

The results showed that there was an improvement in student problem solving skills during Space Geometry learning in the experimental group and control group. Improvements to GeoGebra learning methods are categorized in high improvement, while conventional learning methods are categorized in moderate category.

CONCLUSION

Based on the results and discussions in the research that has been done, it shows that GeoGebra-based space geometry learning can improve problem solving skills. In the experimental group, the increase in problem solving skills in the category was high, while in the control group improved problem solving skills in the medium category. Further research can be focused on the utilization of GeoGebra based on other cognitive aspects. There is an opportunity for further research to explore GeoGebra on other learning materials.

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