Teaching spatial geometry with geogebra: can it improve the problem-solving skills of prospective mathematics teachers?

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Abstract. Research aimed to obtain an overview of improving prospective mathematics teacher students' problem-solving skills by implementing GeoGebra in spatial geometry lectures. The research will be carried out at Universitas Tidar in the second-semester students of the Mathematics Education study program's geometry class. This study used a quasi-experimental method, with a pretest-posttest non-equivalent control group research design. 71 students were selected as research subjects who were divided into two groups, one group as an experimental group (36) who received GeoGebra-based spatial geometry lectures and one group as a control group (35) who received conventional spatial geometry lectures. The instruments used were the lecture implementation observation sheet, pretest, post-test, and student response questionnaires after using GeoGebra during lectures. Based on the post-test results, the experimental group's problem-solving skills increased significantly compared to the medium category's control group. Besides, the description of the response questionnaire results also shows that there are positive impacts obtained by students, including increasing motivation and interest during lectures.

1. Introduction
As a prospective math teacher, students are required to be able to convey the concept back to their students in school later. Therefore, prospective math teachers must be equipped with problem-solving skills, which is one of the must-have abilities because problem-solving skills can make us think logically, critically, and creatively. Problem-solving is recognized as an essential life skill because it involves various processes, including analyzing, interpreting, reasoning, predicting, evaluating, and reflecting [1].

The National Council of Teachers of Mathematics explains that mathematical problem-solving skills need to be developed in learning mathematics [2]. Students should be allowed to apply and adapt various strategies that are appropriate to solve problems. Therefore, each lecture must be designed so that it can provide students with maximum problem-solving skills. One of the problem-solving steps popularized by Polya consists of four steps, namely: 1) understanding the problem, 2) designing a plan, 3) implementing the plan, and (4) reviewing the original answer [3].

Problem-solving skills also have an essential place in the main objective of a curriculum [4]. In the Mathematics Education study program at Tidar University, students are provided with one of the compulsory courses, namely spatial geometry. This subject is vital for prospective mathematics teacher students because it is widely available in the curriculum of mathematics subjects taught at the primary and secondary school levels. Therefore, students must have and develop problem-solving...
skills, considering that their task later when they become teachers teaches students to solve math problems.

The importance of math problem skills in the concept of space geometry for prospective mathematics teacher-students is contrary to the field's existing conditions. Research results indicate that spatial geometry is a complex subject. The preliminary observations indicate that student problem-solving skills are still low, as indicated by the fact that more than 60% of students score less than 70 with a maximum score of 100. The low problem-solving skills are due to the lecture process being carried out. This is under the results of interviews with several students, including 1) the lecture process uses more of the lecture method, and 2) the lecture process has not used technology to provide visualization of material and concepts. Hanafi [5] argued that the difficulty in learning geometry for students was in the high category due to the ineffective lecture process. The same findings were also supported by researchers in early observations of several prospective math teachers who had already received space geometry courses, who had not shown any interest in learning.

Space geometry is one of the courses offered in semester 2 at the Mathematics Education study program, Tidar University. According to the curriculum, this course contains a discussion of geometric objects (points, lines, fields) in space, the relations between geometric objects, many-plane, pyramids, prisms, cones, tubes, spheres, measurements involving objects and geometric forms of space, construction techniques of drawing space and the relations between objects geometry space [6]. The standard of competence for this lecture is that students can understand and have good spatial responsiveness, master concepts, and solve building space problems. There are still many students who solve class geometry problems algorithmically and procedurally [7].

To solve the above problems, a solution is offered by using Geogebra in the space geometry course. Abramovich defines GeoGebra as a free online software application to study geometry, algebra, and calculus at different grade and teaching levels [8]. GeoGebra is designed to combine the features of a dynamic geometry software (Cabri, Geometer Sketchpad) and computer algebra systems (Derive, Maple) in a single, integrated, easy-to-use system for teaching and learning mathematics [9]. There are seven menus in GeoGebra: File, Edit, View, Options, Tools, Window, and Help. GeoGebra also has several tools for visualizing two-dimensional objects, such as points, lines, plumb lines, polygons, circles, ellipses, angles, reflections on lines, slices, and moving graphic views. This menu helps us to visualize geometric objects according to our purpose [6].

Based on the above description, a research question is 1) how to describe improving problem-solving skills of prospective math teachers applying GeoGebra and using conventional learning on space geometry lectures, 2) how students respond to space geometry learning using GeoGebra. This research is considered very important to be carried out to meet the demands of lecture standards in LPTK to apply learning technology to prospective teachers and help prospective teachers improve their problem-solving skills.

2. Methods
This research method uses a quasi-experimental method, with the pretest-posttest non-equivalent control group. This study used two groups, one group as an experimental group who received GeoGebra-based spatial geometry lectures and the other as a control group who received only spatial geometry lectures without using GeoGebra. The design referred to is shown in Table 1.

| Table 1. Research Design |
|--------------------------|
| Experiment | T1 | X | T2 |
| Control | T1 | C | T2 |

Description:
T1 = pretest problem-solving skills
X = application of GeoGebra-based space geometry learning
C = application of conventional method space geometry learning
T2 = post-test problem-solving skills
The instruments used in this study were test questions and questionnaires. The test instrument uses a description test to measure students' ability to problem-solving skills. The test was carried out before being given treatment (pretest) and after being given treatment (post-test). The pretest and post-test were carried out once. The large calculation of the increase in students' problem solving skills used the normalized gain equation, namely with criteria a) low if \(<g><0.3; b) moderate if 0.7><g> ≥ 0.3; c) high if \(<g> ≥ 0.7 [10]. The questionnaire consists of 15 statement items with 4 strongly agreeable, agreeable, disagree, and strongly disagreeable criteria.

The research was conducted at Tidar University in the second-semester students of the geometry lecture in the Mathematics Education study program. The independent variable in this study is GeoGebra-based space geometry lectures. The dependent variable is problem-solving skills.

Analysis of the improvement in problem-solving skills, with the following steps: 1) scoring the results of the pretest and post-test according to the criteria and rubric of the assessment made then adding up all the scores obtained, 2) calculating the average normalized gain score (N-Gain) to determine the increasing problem-solving skills, 3) calculating the total number of scores per item and look for the average score of each item.

3. Results and Discussion

This study used two groups, one group as an experimental group that received treatment using GeoGebra and the other group as a control group who received conventional learning treatment. This research was conducted by taking a sample of space geometry subjects. The learning process carried out in the two groups went through the following stages: 1) implementing the initial test (pretest), 2) providing treatment with conventional learning for the control group, and learning using GeoGebra for the experimental group, and 3) giving the final test (post-test) and questionnaire student responses after being given treatment.

The results showed that there was an increase in the problem-solving ability of Spatial Geometry after students did the learning using GeoGebra assistance. The results of the students' ability to problem-solving skills in Space Geometry can be seen in Table 2. Based on table 2, the average pretest score was 63.6, and the post-test average score was 83.9 in GeoGebra-assisted learning. Whereas in conventional learning, the average pretest score was 61.4, and the post-test average score was 82.8.

Table 2. Comparison of Pretest and Postest Results between Experimental Group and Control Group

|       | Pretest | Postest | Category | N | X   | <g> |
|-------|---------|---------|----------|---|-----|-----|
| GeoGebra | 35      | 61,4    | medium   | 35 | 82,8 | 0,55 |
|        | 36      | 63,6    | medium   |

Based on Table 2, it can be seen that the average post-test score of students is higher than the pretest of the two learning models. These results indicate that there is an increase in problem-solving skills between before and after being given treatment. The gain normality test shows that there is an increase of 0.56 for the use of GeoGebra and 0.55 for conventional learning. The improvements for both GeoGebra learning methods are categorized as moderate improvements. The higher increase from the gain normality test shows that learning Space Geometry using GeoGebra better contributes to improving students' problem-solving skills to spatial geometry.

Table 3. Percentage Increase in Concept Understanding Ability

| Category | Experiment | Control |
|----------|------------|---------|
| High     | 48,6%      | 47,2%   |
| Medium   | 28,6%      | 30,6%   |
| Low      | 22,9%      | 22,2%   |

Based on Table 3, it can be seen that the percentage increase in student problem-solving skills towards Space Geometry in the experimental group was 48.6% for the high category, 28.6% for the medium category, and 22.9% for the low category. The control group increased 47.2% for the high
category, 30.6% for the medium category, and 22.2% for the low category. Overall, both the experimental group and the control group had an increase in problem-solving skills towards Space Geometry.

![Graph](image)

**Figure 1.** Presents Improvement of Student Problem Solving Skills to Space Geometry

Based on the analysis of student responses, the researcher found few results presented in Figure 2 below.

![Image](image)

**Figure 2.** The answer of one of the students to question number 3

Figure 2 answers one of the students to question number 3, which makes the picture not what the question wants. The student draws the intersection of two planes on the ball at the top only. Meanwhile, what is meant by the intersection of the two fields on the ball at the top and bottom? However, the process can be correct because it is under the formula to answer the problem. Likewise, the process steps are under the problem-solving indicators, namely understanding the problem, planning the work, doing calculations, returning to see the original answer. Sketches in student problem solving also show that GeoGebra can build, solve and illustrate math problems [11].

The results of this study are in line with Saha, Ayub, and Tarmizi. They have identified the impact of the use of GeoGebra on the teaching of coordinate geometry on a group of middle school students [12]. The results show a statistically significant difference between the two groups' post-test means within the superior GeoGebra group. Also, GeoGebra is beneficial for demonstrating and visualizing mathematical concepts related to geometric objects, especially [13].

Problem-solving is a process used to solve problems. Problem-solving skills are fundamental in the learning process of mathematics [14]. Carreira et al. [15] also explained that problem-solving is a type of activity that requires experimentation, exploration, investigation, testing, reflection, and discussion.
According to Slameto, problem-solving is seen as a process to determine the combination of several rules applied to overcome a new situation [16].

The questionnaire contains statements relating to student responses to GeoGebra-based space geometry learning. The results of student response recapitulation can be seen in the following table.

| Item number | Statement (+/-)                                                                 | Average score per item | Description |
|-------------|--------------------------------------------------------------------------------|------------------------|-------------|
| 1           | I can visualize and answer questions after learning activities with a GeoGebra.  | 2.94                   | Agree       |
| 2           | GeoGebra software-assisted mathematical learning media using easy-to-apply menus | 3                      | Agree       |
| 3           | GeoGebra software-assisted mathematical learning media cannot be used in geometry courses in fields and spaces. (-) | 2.94                   | Disagree    |
| 4           | GeoGebra software is not able to perform accurate calculations of geometry questions. (-) | 2.8                    | Disagree    |
| 5           | I can think more creatively and critically in discussions when using GeoGebra.   | 2.91                   | Agree       |
| 6           | I am more active during the learning process by using GeoGebra software-assisted mathematical learning media | 2.61                   | Agree       |
| 7           | I can't design and create geometry builds with GeoGebra applications. (-)       | 2.72                   | Disagree    |
| 8           | Learning with GeoGebra software-assisted mathematical learning media made me better understand learning materials. | 2.86                   | Agree       |
| 9           | The media of mathematics learning assisted by GeoGebra software raised many questions because it aired some compelling images. | 2.88                   | Agree       |
| 10          | After learning, I can work on the problem more efficiently.                    | 2.97                   | Agree       |
| 11          | During my studies using GeoGebra software, I always ask questions that I do not know to either friends or lecturers. | 3.02                   | Agree       |
| 12          | I can more easily explain geometry material by using GeoGebra.                 | 2.80                   | Agree       |
| 13          | While studying GeoGebra, I felt that what I learned became more real.         | 3.08                   | Agree       |
| 14          | I'm not interested in explaining geometry with geoGebra because it's more complicated. (-) | 2.77                   | Disagree    |

From Table 4 it can be seen that the results of the recapitulation of student responses show that of the fifteen statements, which are the translation of the 4 indicators, namely the skills in understanding problems, designing mathematical models, solving models, and interpreting the solutions obtained. All positive statements were dominant in agreeing, while in the negative statements, the dominant respondents chose to disagree. This shows that students agree that learning GeoGebra-based spatial geometry can improve problem-solving skills. Learning Space geometry using GeoGebra can help students build new knowledge and connect it with previous knowledge [17]. It can also improve students' ability to conceptualize elements of mathematics to improve learning outcomes [18]. GeoGebra can be used for active, problem-oriented teaching and fosters mathematical experiments and discoveries both in the classroom and at home [11]. The results showed an increase in students' problem-solving skills during space Geometry learning in the experiment and control groups. The improvement of GeoGebra learning methods and conventional learning methods categorized in the medium.

4. Conclusion

In conclusion of this study, problem-solving skills in the experimental group and control group increased significantly. Both groups improved in the moderate category, but student problem-solving skills were higher in the experiment group. Besides, the description of the response questionnaire results also shows that there are positive impacts obtained by students, including increasing motivation.
and interest during lectures. This research is limited to space geometry material. Further research can be focused on GeoGebra utilization based on other cognitive aspects. There are opportunities for further research to explore GeoGebra in other material content.

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