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Improving Student Geometry Problem-Solving Skills Through Spatial Training

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ABSTRACT

Problem-solving is an integral part of learning mathematics, and geometry is one of the basic subjects of mathematics. However, students' geometric problem-solving skills are relatively lacking due to some factors, including spatial skills. There is a significant relationship between spatial skills and problem-solving. Therefore, spatial training needs to be implemented in schools to improve students' geometric problem-solving skills. This study aimed to determine the improvement of students' geometric problem-solving skills through spatial training. The research employed a quantitative method. The participants were 8th-grade students from one of the junior high schools which consisted of 30 students. The research instrument was a test of geometry problem-solving skills. Data on students' geometry problem-solving skills were analysed using paired t-test and normalised N-gain. The results showed that there was an increase in students' geometric problem-solving skills through spatial training. It can be said that spatial training can improve students' geometry problem-solving skills. This research implies that spatial training can be carried out ongoingly to achieve better learning outcomes.

Keywords: *Problem-solving Skills, Geometry, Spatial Reasoning, Spatial Training.*

1. INTRODUCTION

Problem-solving skill is fundamental in learning mathematics [1]. The importance of problem-solving skills is confirmed by NCTM [2], stating that in learning mathematics, problem-solving is integral. Mathematicians and mathematics educators agree that problem solving is at the heart of mathematics teaching and learning [3]. The need to develop mathematical problem-solving skills is due to the evolving nature of society, so students need to be facilitated to develop their mathematical problem-solving skills [4].

One of the fundamental components in learning mathematics is geometry [2]. Geometry discusses contents related to points, lines, planes, spaces, spatial images, and their relationships [5]. Objects in geometry are abstract that can only be imagined, although some object properties can be represented by models or props. Geometry is fundamental to studying advanced topics in mathematics, science, geography, architecture, art, design, engineering, and technology in college or graduate studies [6]. Geometry is one of the important topics taught from elementary school to college. However, students' geometry problem-solving skills remain low [7,8] due to some factors, including the students' spatial skills [6]. This is because geometry highly relies on spatial reasoning [9]. Geometry is even referred to as a clear and rich object for spatial reasoning [10].

Spatial reasoning has always been a significant capacity for human activity and thinking. Recently, the recognition of the importance of spatial reasoning is increasing in mathematics, across other disciplines, and in daily life [10]. With the broad implications of spatial skills, it is critical to ensure that junior high school students gain spatial reasoning experience and habits. Spatial reasoning helps students understand 3D objects and spaces by mentally engaging themselves in spatial situations to solve problems and contextualize spatial elements [11]. This condition is enabled by a significant relationship between mathematical problem-solving and spatial skills [12]. Spatial skills are referred to as special skills supporting geometric problem-solving. Students with high spatial skills use more spatial skills to solve geometry problems [4]. However, to date, there is still limited research that discusses the development of students' geometry problem-solving skills after being given spatial skills training. Previously, there have been many studies related to spatial training where the training can improve students' mathematical performance and spatial reasoning skills [13], spatial training has an impact on a significant increase in mathematical performance and spatial reasoning which is influenced by spatial visualization training [14], spatial training can improve students' spatial visualization skills and students' retention [15], spatial training can significantly improve students' mental rotation skills [16, 17], and spatial training can also improve students' spatial and numerical skills as an initial geometry instruction [18]. However, the research that investigates the improvement of students' geometry problem-solving skills through spatial training still does not exist. Whereas the skill to solve geometric problems is one of the fundamental skills that must be given attention in mathematics. Therefore, researchers are interested in investigating the improvement of students' geometry problem-solving skills through spatial training. Furthermore, based on references from previous research, that spatial training has been widely carried out, but most of the samples involved are elementary or undergraduate students, only a few who carry it out in secondary schools [19]. So that, the spatial training in this study is aimed at junior high school students. Another reason is that geometry problems solving questions involving spatial skills are often found in several test questions at the junior high school level, so it is important for junior high school students to be familiarized and trained in spatial reasoning in learning mathematics so that they are easy and responsive in solving math problems.

Previous studies on spatial training generally concluded that spatial training is an activity training spatial indicators that are carried out continuously within a certain period using several effective methods to improve spatial reasoning skills [13,14,15,16,17,18,20,21]. The indicators of spatial reasoning are spatial visualisation, mental rotation, and spatial orientation [22]. However, the main focus of this study was to train students' spatial visualisation skills because the spatial visualisation indicator is considered appropriate to the level of students' intellectual development. It is also often found in several junior high school exam questions, such as competency test questions in student textbooks, problem-solving problems, and Olympiad questions. Based on the use of spatial visualization skills that are widely available in mathematics learning, the authors are motivated to train students' spatial visualization skills as an effort to improve students' understanding in solving mathematical problems. The results of this study, such as the design of learning activities and student worksheets that have been designed in the form of spatial training can be used and developed by further researchers in order to create a module as a guide for students' spatial training. Then, the results of this study also serve as a reference by other teachers in spatial training to students, especially on cubes and cuboids. This research implies that spatial training can be carried out continuously to get better results.

2. METHODS

This study aimed to investigate the improvement of students' geometric problem-solving skills through spatial training. The objective of the study was achieved by gathering data on students' geometry problem-solving skills. The data was collected through geometry problem-solving skill tests before and after the spatial training (pretest-posttest). Data on students' geometry problem-solving skills were analysed using paired t-test to determine the improvement of students' geometry problem-solving skills [23,24]. Next, the N-gain test was conducted to see how well the students' geometric problem-solving skills improved through spatial training.

There were 30 junior high school students involved in this study and were given approval by the school to implement spatial training in the amount of two and a half weeks of learning, 5 times face-to-face. One meeting consists of 80 minutes and 120 minutes. The spatial training activities in this study are to provide additional spatial assignments to students on each topic taught both during core learning activities and afterwards. This activity is integrated into a learning model, specifically the Discovery Learning model. Harahap [25] argued that the Discovery Learning model can improve students' spatial skills, and thus, spatial training is incorporated in the Discovery Learning model. Some of the methods used in this spatial training activity are (1) image animation [26] using digital aids, namely illuminations: cube Nets from Lowrie, Logan, & Hegarty [14]. During the learning activities, students were introduced to the Illumination Cube Nets application, which can visualise cube nets into a cube or vice versa. This application also trains students in determining the bottom and upper sides of the cube.

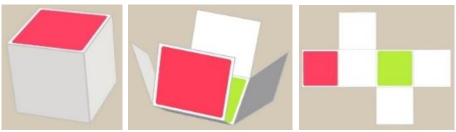


Figure 1 Illumination Cube Net Application.

(2) The next method used in spatial training is an online video game [27,28] related to cube nets. The games provided were the ones that could train children's spatial skills, especially their spatial visualisation skills. Figure 3 is an online game played by students for a certain duration. This online game displays images of cube nets. Students would answer "yes" if the net can form a cube and answer "no" if it cannot form a cube.

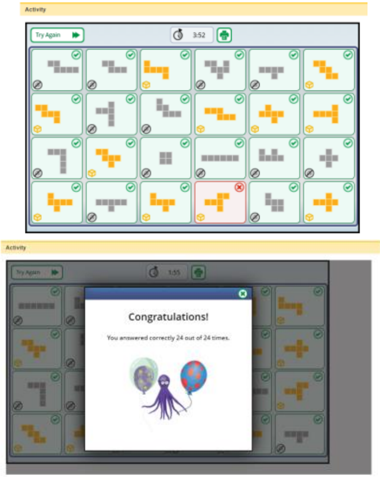
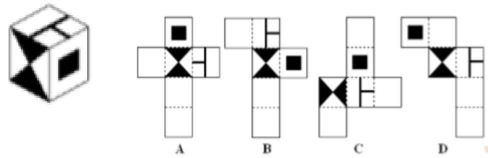


Figure 2 Cube Nets Online Video Game Applications.

Students played this game as an exercise and reinforcement for students in understanding cube nets after the activities to find various kinds of cube nets using the Discovery Learning model, and (3)

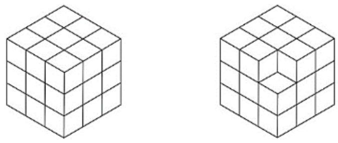


A

B

Figure 3 Example of Spatial Task Exercise by Newton and Bristoll [29].

The problems given were designed in a spatial form, but the objective is that students can solve problems related to cubes and cuboids. Students were shown a 3 cm x 3 cm x 3 cm cube in Figure 4a and asked to determine the volume and surface area of the cube after removing a unit cube, as shown in Figure 4b.



(a) **(b)**

Figure 4 Examples of Spatial Task Exercises Related to Cube Volume.

This technique was done to familiarize students with thinking spatially and make it easier to solve problems.

3. RESULTS AND DISCUSSION

The descriptive statistical tests on the geometry problem-solving skill test revealed that the average pretest score was 6.77 (SD=3.617) and the average posttest was 24.03 (SD= 8.269) so that the N-Gain was 0.5269. The detailed results of the pretest, posttest, and N-gain data are presented in Table 2.

Table 1. Data on Student Geometry Problem Solving Skills Scores

Skills	Score	N	$\bar{x}$	SD
Geometry problem-solving	Pretest	30	6.77	3.617
	Post-test	30	24.03	8.269
	N-Gain	30	0.5269	0.22678
Maximum Score= 40				

Another training method is practicing spatial problems [27,28]. The spatial training given were problems related to the cube and cuboid delivered that day and presented in a Student Worksheet. For example, students were shown a cube in Figure 3a and asked to choose the correct net in Figure 3b.

The average pretest and posttest scores in Table 1 show an increase in students' geometry problem-solving skill scores after spatial training. However, it is necessary to paired t-test to determine the difference in the average results of the pretest and posttest scores and examine the increase in students' geometric problem-solving skills after implementing spatial training.

The requirement for conducting the Paired t-test is that data should be normally distributed. The statistical hypothesis to test the normality of the pretest and posttest data for each aspect is as follows.

H_0 : The sample comes from a normally distributed population

H_a : The sample comes from a population that is not normally distributed.

The pretest score normality test was carried out using the Shapiro Wilk test through the SPSS 20, with the following test criteria.

If the value of Sig.(p-value) < (α = 0.05), then H_0 is rejected

If the value of Sig.(p-value) (α = 0.05), then H_0 is accepted

The Normality Test of the pretest data through the SPSS 20 program found that the pretest score of students' geometry problem-solving skill with a p-value of 0.482 (α = 0.05). So, H0 was accepted, meaning that the sample came from a normally distributed population or the students' initial geometry problem-solving skills are normally distributed. Data of the normality test of the students' geometry problem-solving skill pretest data is presented in Table 2.

Furthermore, the normality test was also conducted for the post-test data on students' geometry problem-solving skills and resulted in a p-value of 0.269 (α = 0.05). 0.05. So, H0 was accepted, meaning that the sample came from a normally distributed population. This shows that the students' geometry problem-solving skills after spatial training were normally distributed. The detailed results are presented in Table 3.

Based on Table 2 and Table 3, it can be concluded that the initial and final data on students' geometry problem-solving skills were normally distributed. As the normality test conditions were met, the next step was to test the improvement of students' geometry problem-solving skills using paired t-test. This study hypothesises an increase in students' geometric problem-solving skills through spatial training, as follows.

H_0 : $\mu_1 = \mu_2$, there is no increase in students' geometry problem-solving skills through spatial training.

Table 2. Data of Normality Test Results for Geometric Problem-Solving Skills Pre-test Score

Results	*Shapiro-Wilk*			Decision
Pretest	Statistic	Df	Sig-	
	0.968	30	0.482	H_0 accepted

Table 3. Data on Normality Test Score of the Geometric Problem-Solving skills Post-test

Results	*Shapiro-Wilk*			Decision
Posttest	Statistic	Df	Sig-	
	0.958	30	0.269	H_0 accepted

Table 4. Paired T-Test Results of Students' Geometry Problem-Solving Skills

Paired Samples t-test									
		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test - Post-test	-17.267	7.201	1.315	-19.956	-14.578	-13.133	29	.000

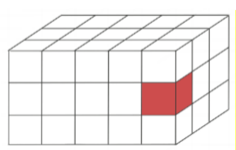
$H_a : \mu_1 > \mu_2$, there is an increase in students' geometric problem-solving skills through spatial training.

Hypothesis testing was done using paired sample t-test. The paired t-test undertaken using SPSS 20 resulted in the p-value if 0.000 ($\alpha = 0.05$). So, it was decided that H0 was rejected and Ha was accepted. In other words, the hypothesis of "there is an increase in geometry problem-solving ability through spatial training" was accepted. Therefore, it was concluded that there was an increase in students' geometry problem-solving skills through spatial training. The paired sample t-test are presented in Table 4.

The results of the paired t-test indicate an increase in students' geometry problem-solving skills through spatial training. Furthermore, to examine the extent of the improvement of students' geometry problem-solving skills, the N-gain test was conducted using SPSS 20 and obtained an average value of 0.5269, as shown in Table 1. The N-gain score of 0.5269 is within the interval of 0.3 and 0.7, meaning that the N-gain score is good. Hence, it can be said that the improvement of students' geometry problem-solving skills through spatial training is included in the good category.

This study showed that students' geometry problem-solving skills can be improved by training students' spatial skills, especially spatial visualization skills. Although the N-gain value obtained is not too high, the changes in students' geometry problem-solving skills can be seen clearly before and after spatial training is applied. The acquisition of the average pretest score of students' geometry problem-solving skills before the implementation of spatial training was 6.77. Then, the average value of students' geometry problem-solving skills becomes 24.03 from the ideal maximum score of 40 after being trained in spatial abilities. The increase in geometry problem-solving skills after being given spatial training can be seen from the percentage of student success in solving one of the following geometry problem-solving skills.

"Here is a picture of a cuboid composed of several unit cubes measuring 1 cm x 1 cm x 1cm. If the colored unit cube is removed from the cuboid, find the current surface area of the cube".



The success rate of this question is 66% compared to the previous which is 0%. One of the descriptions of students' answers who have answered this problem correctly is as follows.

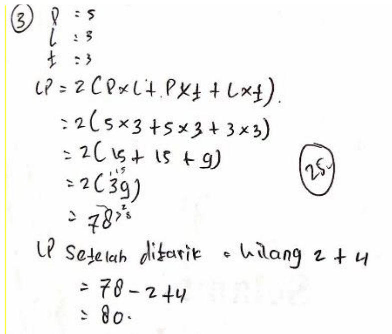


Figure 5 Example of Student's Answers in Solving Geometry Problems.

Based on the description of the student's answers, it can be seen that there is an impact of spatial ability when solving the problem of the surface area of the cuboid. It can be seen that when students can correctly determine the missing sides and the sides that appear after a unit cube is drawn from the cuboid by writing "missing 2 + 4". This shows that he can imagine a cuboid after a cube is drawn in which two sides are missing and 4 sides are visible. He can see the previously invisible sides become visible after being drawn by a unit cube without seeing the real thing, but by imagining the object. So, it can be said that in the process of solving the problem of the cuboid surface area, students take advantage of their spatial visualization skills which can help students in representing the given problem.

This shows that spatial ability is very influential in solving geometric problems. In line with the results of previous studies which stated that many participants had difficulty in solving mathematical problems. The challenge faced by participants is not in their mathematical knowledge, but in representing problems that require strong spatial abilities [12]. In his research, said that for many people, simple problems in mathematical content can be difficult to solve even when the mathematical procedures are simple. This is because when given a simple problem, 68% of the students in their research misrepresented the given problem. this can be affected by the quality of the visualization produced during solving the problem. He concluded that students with high spatial abilities performed significantly better in solving and representing a problem than students with low spatial abilities. This is also in accordance with the results of other studies which stated that students who have high spatial abilities use more their spatial abilities in solving problems [4].

The results of this study can be used as a reference for other teachers to implement spatial training in improving students' geometric problem-solving skills. This is because there are so many junior high school level exams that use mathematics questions that require high spatial ability.

Several spatial training activities have been written on students' worksheets as a guide for students. Students have also been asked to install the Illumination Cube Net application on each individual's android so that students can easily work on spatial tasks that are applied by the teacher. However, it would be even better if there was a special module that can be used in this spatial training. There are currently no modules or special teaching materials that can be used by teachers in teaching geometry materials in schools which include spatial exercises. Thus, further researchers can develop a module or spatial training teaching material that can help teachers to apply it in schools.

In addition, the main focus in this study was only to train students' spatial visualization ability indicators. This is because the spatial visualization indicator is considered appropriate to the level of students' intellectual development and is often found in several junior high school exam questions, such as competency test questions contained in student textbooks, problem-solving questions, and olympiad questions. It is hoped that further researchers can train other spatial indicators such as spatial orientation and mental rotation to find geometric concepts, this is because spatial orientation is also needed in solving problems of everyday life.

4. CONCLUSION

Based on the research results about students' geometric problem-solving skills through spatial training for Year 8 students, it can be concluded that there is an increase in students' geometric problem-solving skills through spatial training. It can be seen from the use of spatial abilities by students in solving geometry problems. Most of the students' success in solving geometry problems is influenced by their spatial ability. Students with high spatial ability can easily understand and plan the solution of a problem.

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