Spatial Skill Profile of Mathematics Pre-Service Teachers

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Abstract. This study is aimed to investigate the spatial intelligence of mathematics pre-service teachers and find the best instructional strategy that facilitates this aspect. Data were collected from 35 mathematics pre-service teachers. The Purdue Spatial Visualization Test (PSVT) was used to identify the spatial skill of mathematics pre-service teachers. Statistical analysis indicate that more than 50% of the participants possessed spatial skill in intermediate level, whereas the other were in high and low level of spatial skill. The result also shows that there is a positive correlation between spatial skill and mathematics ability, especially in geometrical problem solving. High spatial skill students tend to have better mathematical performance compare to those in two other levels. Furthermore, qualitative analysis reveals that most students have difficulty in manipulating geometrical objects mentally. This problem mostly appears in intermediate and low-level spatial skill students. The observation revealed that 3-D geometrical figures is the best method that can overcome the mentally manipulation problem and develop the spatial visualization. Computer application can also be used to improve students’ spatial skill.

1. Introduction

Problem solving ability is one of the main goals in learning [1]. Someone will do the mental process using all the knowledge possessed and determine the right strategy to solve the problem. Polya [2] discussed two kinds of problems, namely (a) problems to find, can be theoretical or practical, abstract or concrete, including puzzles, and (b) problems to prove, to show that a statement is true or false). In mathematics, problems usually take the form of math problems, but not all math problems considered as a problem. Based on the results of preliminary observation and interviews with several mathematics teachers in junior high school, many students have difficulty in solving mathematical problems related to geometry. This is because students find it difficult to imagine an object in their minds. The ability to visualize objects into the student's mind, is often referred as spatial ability. Sorby [3] stated that spatial ability is a mental process involving the ability to move things mentally and change the point of view when looking at an object.

Spatial ability of a person can affect mathematical ability, this is supported by the results of research showing that spatial ability has a positive relationship with students' ability to solve problems ([4], [5], [6], [7]). The field of science in mathematics that most often requires spatial ability is geometry. To overcome such problems, the teacher has done various ways during the learning process. However, scaffolding given by teachers sometimes lacks the spatial aspect, so that students with low spatial skills will tend to have trouble in understanding the material provided ([8], [9], [10]). To train and improve students' spatial skills, teachers must be able to bridge the real world with the minds or imaginations of students [3].

The goal of this research is describing the spatial ability of mathematics pre-service teachers. So it is expected to see the extent to which spatial ability affects a person's ability to solve mathematical problems related to geometry. Knowing this will create appropriate scaffolding for geometric material with respect to the spatial ability aspect. The main reason for conducting this research to junior high
school students is that students are in the early stages of formal operations, meaning students have started thinking abstractly [11]. Considering that there is need for learning that takes into account every aspect of the student’s ability, in this case is spatial ability.

2. Method
Quantitative research method was used to investigate pre-service teachers’ spatial ability. This research was conducted at Universitas Islam Majapahit, Mojokerto. The participants of this research were 25 mathematics pre-service teachers that already took Geometry course. Three instruments were used to collect data in this study. First instrument was spatial ability test, The Purdue Spatial Visualization Test (PSVT) that known as The Purdue Visualization of Rotations (ROT). This test is adapted from spatial visualization test that was developed by Dr. Roland Guay in 1976 from Purdue University. The main purpose of this test is to assess the ability to visualize rotated objects. This test consist of 30 problems in spatial rotation visualization, shown below as an example

![Problem in PSVT](image)

On this test, there are three directions for participants to solve the problems [12]
1. Observing how the three-dimensional object in the first row is rotated.
2. Examining what if the object in the second row is rotated in the same direction.
3. Selecting among the five possible answers (A, B, C, D, and E) in the third row.

The participants were divided into three categories based on the spatial ability test result. The three categories were high, intermediate, and low level of spatial skills. Scoring level of the spatial ability test based on this table:

| Score (x) | Category     |
|-----------|--------------|
| 1. 80 ≤ x ≤ 100 | High        |
| 2. 60 < x < 80  | Intermediate |
| 3. 0 ≤ x ≤ 60  | Low          |

The second instruments were mathematical ability test that consist of five problems related to geometry subject. This instrument was used to measure the participants’ ability in solving geometry problems so that the correlation between spatial ability and geometrical problem solving ability can be known.

The third instrument was questioner that consists of 20 questions about the participants’ perspective about learning Geometry. The questioner was written in Bahasa Indonesia as the participants’ nationality language.

3. Results
Data of spatial ability were collected in the second week of the semester, so that initial ability of the 25 participants can be measured. Sixty minutes was given to the participants to solve the Purdue Spatial Visualization Test (PSVT) and each number must be done in 2 minutes. The result shows that mostly participants had intermediate level of spatial ability, and the rest were in high and low level of spatial skill. The table below shows the percentage of spatial skills possessed by the participants

| Number of Participants | Percentage (%) | Category               |
|------------------------|----------------|------------------------|
| 5                      | 20             | High Spatial Ability   |
| 17                     | 68             | Intermediate Spatial Ability |
| 3                      | 12             | Low Spatial Ability    |

Most participants got wrong answers for several same numbers, such as: 16, 24, 28, 30. The three-dimensional object in those numbers are rotated around more than one axis as the picture shown below

![Two times rotated object](image)

**Figure 2.** Two times rotated object

The participants in the high level of spatial ability were the only group who could answer those numbers correctly. In other hand, none of three participants in the low level of spatial ability had the right answer. The mathematical ability test was done in two times, first time was in the middle of the semester and the last time was in end of the semester as the final test. The result shows that there is a positive correlation between spatial ability and geometrical problem solving ability, in other words participants in the high level of spatial ability tend to have better score than the other group of participants. It can be seen in the picture below.

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The first picture (a) was done by high spatial ability pre-service teacher as the first participant. We can see from the picture, the first participant was able to draw two planes intersect correctly. In this state we can say that the high spatial ability participant was able to imagine the position of the two intersect planes and noticed that the intersection of two planes was a line. The second picture (b) was done by intermediate spatial ability participant. The second participant was not able to draw correctly. According to the interview, the intermediate spatial level participant had difficulty in imagining the intersection, although the intermediate participant understand that the intersection of planes is line. The last picture (c) was done by low spatial level participant. As predicted, the third participant was not able to solve the drawing task.
The questioner was given to the participants in the end of the semester, so that they could respond and analyze the instructional geometry course for the whole semester. The result shows that most participants could understand the geometry material easier if using real 3-D or graphical object to represents geometrical object than just using the pictures in the text book.[13]

4. Discussion and Conclusion

The purpose of this study is investigate the spatial ability of mathematics pre-service teachers and find the best instructional strategy that facilitates this aspect. According to the result of the Purdue Spatial Visualization Test (PSVT), 68% of the participants possessed intermediate level of spatial ability, 20% in the high level of spatial ability and the rest was in the low level of spatial ability as 12%. Participants in intermediate and low spatial ability levels had difficulty in solving spatial rotation problems that the three-dimensional object are rotated around more than one direction. The results support the findings of Caissie, Vigneau and Bord [14], Bordner and Guay [12]who stated that most students have difficulty in solving rotation spatial problems with more than one directions.

The result also shows that there was a positive relation between spatial ability and mathematical ability in geometrical problems solving. Participants in high level of spatial ability tend to had better mathematical ability than the other levels. It was also found in the study was carried out by Turgut and Yilmaz, [4], Rabab’h and Arsaythamby [5], Verdone, et. al. [6], Hannafin et al. [7], and Yenilmez & Kakmaci [15]. According to the questioner results, during the geometry lesson activities, almost all the participants stated that it was easier to understand the geometrical concepts if using real geometrical objects. This result is similar to the earlier study, which was carried by Akayuure, Asiedu-Addo, and Alebna [16] who stated that real geometrical objects would help students understand about geometrical concepts. Geometry computer application was also used during this study to assist the low spatial ability
group understand easily. This method supports the findings of Sorby [3] and Roca-González, et al. [17] who also used virtual technologies to help their students understand the geometry concepts.

In conclusion, the present study primarily confirms previous findings that spatial ability is one of very important aspect in geometry. Learning activities should support students in all levels of spatial ability.

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