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THE EXISTENCE SPATIAL REASONING OF PRESERVICE TEACHER IN PRIMARY MATHEMATICS LEARNING

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Abstract
Spatial reasoning is an ability related to the representation and use of objects and their relationships in the 2D and 3D worlds. This research examines the spatial reasoning' of pre-service teacher primary education and its use in their course. The subject involved 120 pre-service teachers (60 second years students; 60 third years students; 37 males; 83 females) in the primary education department of Universitas PGRI Madiun. The measurement uses a spatial reasoning test based on three constructs: spatial visualization, mental rotation, and spatial orientation (20 items spatial visualization; 20 items spatial orientation; 20 items mental rotation). The test was used to choose subjects with high spatial ability in every three aspects. Then, the selected subject was observed to view the use of spatial reasoning ability. This research results in spatial reasoning ability used to explain objects, draw objects, and the relations between objects in the classroom. That is the possible way to improve student achievement through spatial reasoning ability used by teachers.

Keywords
Primary mathematics learning, spatial visualization, mental rotation, spatial orientation

INTRODUCTION

In preparing students to master a variety of disciplines, pre-service teachers must have spatial literacy skills and the ability to teach these skills to their students (Moore-Russo, Viglietti, Chiu, &

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Bateman, 2013). Spatial Literacy is a person's perception and understanding of spatial objects and their relationships (Lange, 2003). To be spatially literate, one must be able to imagine spatial objects, reasoning about the nature and relationships between spatial objects, and send and receive communications about spatial objects (Moore-Russo et al., 2013).

Spatial Literacy consists of three domains involve visualization, spatial reasoning, and communication (Moore-Russo et al., 2013). The domain of spatial Literacy that has been proven to improve student mathematics performance in elementary schools is spatial reasoning. Spatial reasoning is an ability related to representation, the use of objects and their relationships in a two-dimensional and three-dimensional world (Linn & Petersen, 1985; Williams, Gero, Lee, & Paretti, 2010). Based on this definition, the spatial reasoning scope is the use of two-dimensional and three-dimensional objects (Grossner, 2017; Pittalis & Christou, 2010).

Spatial reasoning has three aspects. These three aspects are spatial visualization, mental rotation, and spatial orientation (Linn & Petersen, 1985; Lowrie & Jorgensen, 2017; Ramful, Lowrie, & Logan, 2017; Williams et al., 2010). Spatial visualization is the ability to describe situations when components move and are compared to each other based on information (Linn & Petersen, 1985; Lowrie, Logan, & Ramful, 2017). Mental rotation is the ability to rotate two- or three-dimensional objects and imagine their position after playback (Lowrie et al., 2017; NCTM, 2006). Furthermore, spatial orientation is the ability to enter certain spatial situations and imagine how the stimulus arrangement will emerge from another perspective (Lowrie et al., 2017; NCTM, 2006). These three aspects are the criteria for one's spatial reasoning ability.

Research on spatial reasoning in the field of mathematics education states that training in the ability of spatial reasoning makes improvements in students' mathematical performance in primary schools (Cheng & Mix, 2014; Lowrie, 2016; Lowrie et al., 2017). A teacher who has good spatial reasoning ability can improve teacher ability in the STEM field (Mulligan, Woolcott, Mitchelmore, & Davis, 2017). Furthermore, spatial reasoning is also a predictor of one's success in the STEM field (Newcombe, 2013; Williams, 2003). Based on previous research, spatial reasoning is a matter that must be considered in primary school learning mathematics.

Research on spatial reasoning is much to suggest that spatial reasoning can improve student math performance in elementary schools. However, the results of the study were obtained by training conducted outside of mathematics learning. Mathematical performance increases with increasing spatial reasoning ability (Cheng & Mix, 2014; Lowrie, 2016; Lowrie et al., 2017; Pradana, Sholikhah, Maharani, & Kholid, 2020; Ramful, Ho, & Lowrie, 2015). This implies that mathematical performance indirectly increases due to spatial reasoning training. In these studies, the teacher directly taught spatial reasoning to students by ignoring the curriculum (Cheng & Mix, 2014; Lowrie, 2016; Lowrie et al., 2017; Sholikhah & Pradana, 2018). Then it raises a question of whether spatial reasoning that encompasses these three aspects exists and can be taught through mathematics learning in accordance with the curriculum, especially in the curriculum in Indonesia.

When a pre-service teacher has a good spatial reasoning ability, whether the ability is used in learning mathematics, the question becomes important considering that spatial reasoning is a predictor of one's success in the field of mathematics (Newcombe, 2013; Pradana & Sholikhah, 2019; Wiker, Schwerha, & Jaraiedi, 2009).

Questions based on previous research are questions relating to the existence of spatial reasoning in mathematics learning. Are these aspects of spatial reasoning ability can be used to perform mathematics learning in accordance with the curriculum in Indonesia? The importance of this is revealed to confirm that spatial reasoning exists and can be adapted to mathematics learning in accordance with the curriculum in Indonesia. Given that spatial reasoning can improve students' mathematical performance

(Cheng & Mix, 2014; Lowrie, 2016; Lowrie & Jorgensen, 2017; Lowrie et al., 2017), then it can be predicted that pre-service teachers who use the ability of spatial reasoning will be able to make learning effective and improve student math performance.

Based on the value of the previous research, this study aims to examine the spatial reasoning' of pre-service teachers in primary education and its use in their courses.

METHODOLOGY

Participants

The subjects of the study were pre-service elementary school teachers in Universitas PGRI Madiun, Madiun, East Java, Indonesia. 120 pre-service elementary school teachers who are second- and third-years students (60 second year students; 60 third year students; 37 males; 83 female). The pre-service elementary school teachers are a collage-student who has taken the course of geometry and learning mathematics in elementary school.

Materials

The instrument used in this study is spatial reasoning test based on three constructs: spatial visualization, mental rotation, and spatial orientation. The test measures every aspect of spatial reasoning by criteria on Table 1. Test construct in multiple choice as 60 items (20 items spatial visualization; 20s item spatial orientation; 20 items mental rotation), in Figure 1.

Assessment of spatial reasoning test

The score of each item is one point for correct answer and zero point for incorrect answer. If any item not answered by participant, the score is zero point. The total maximum score of this test is 60 points. The result of the test categorized as following: 41–60 (high ability); 21–40 (average ability); 0–20 (low ability).

Procedure

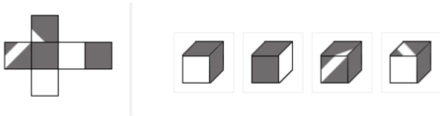
This study begins by providing a spatial reasoning test on the subject. The tests are conducted simultaneously on the same day. The tests were conducted in 6 classes with each class containing 20 subjects. After the tests are given the subject is classified based on spatial reasoning ability (high; average; low). The classification is also specific to each aspect of spatial reasoning.

Table 1
The criteria of spatial reasoning

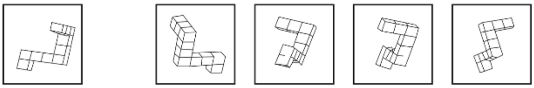
Spatial reasoning aspect	Criteria
Spatial visualization	Visualizing the outcome of folding/unfolding a particular configuration
	Constructing a solid from a given net and vice versa
	Matching pieces and parts
	Finding the symmetry in an object
	Reflecting an object
Spatial orientation	Determining the position of an object relative to that of the observer
	Reading maps from different perspectives
Mental rotation	Determining the outcome of a rotation of a 2D and 3D object
	Differentiating between reflection and rotation

Figure 1

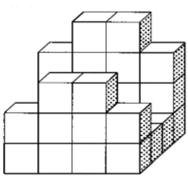
Sample item: (1) Spatial visualization test; (2) Mental rotation test; (3) Spatial orientation test



(1) Spatial visualization test



(2) Mental rotation test



Which one the left view of this figure!

(3) Spatial orientation test

Based on the classification, subjects were chosen with high criteria on spatial reasoning as well as on each of the three aspects. The main reason chosen subject with high criterion is that the subject potentially uses the ability of spatial reasoning in teaching elementary school mathematics. After the subject is selected, the subject is facilitated to do the classroom learning. Subject teach mathematics in the field of geometry. During the learning, subjects were observed with the aim of whether the subject showed symptomatic use of spatial reasoning in learning. The observation criteria are based on the three aspects of spatial reasoning (spatial visualization, spatial orientation, and mental rotation). To strengthen research data after learning, subjects interviewed to be able to know and confirm the actions of the subject at the time of learning is a symptom of the existence of spatial reasoning.

Data analysis

We analyzed the spatial reasoning test result in three categories (high, average, and low). The data from observation analyze by describing spatial reasoning categories in terms of spatial visualization, spatial orientation, and mental rotation.

RESULTS

The results of spatial reasoning tests conducted based on aspects of spatial reasoning are spatial visualization, mental rotation, and spatial orientation, presented in Table 2.

Table 2

The criteria of spatial reasoning

Classification	Interval score	Number of participants		Total
		2nd year	3rd year	
High ability	41–60	6	7	13
Average ability	21–40	34	39	73
Low ability	0–20	20	14	30

Figure 2

Mean value of spatial reasoning in each aspect

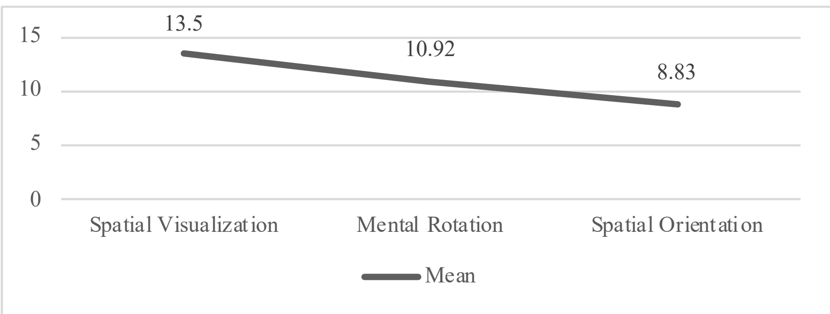


Figure 3

Mean value of spatial reasoning student based on year

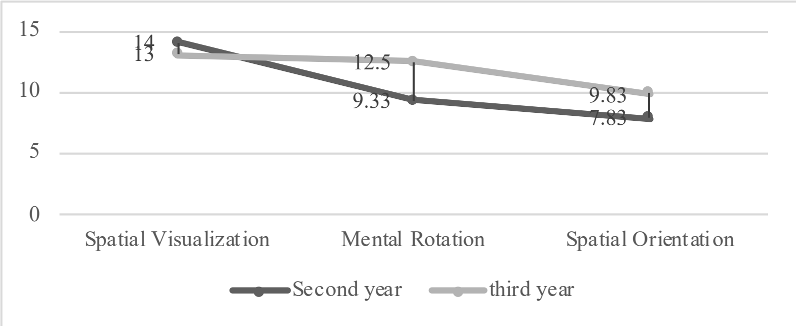
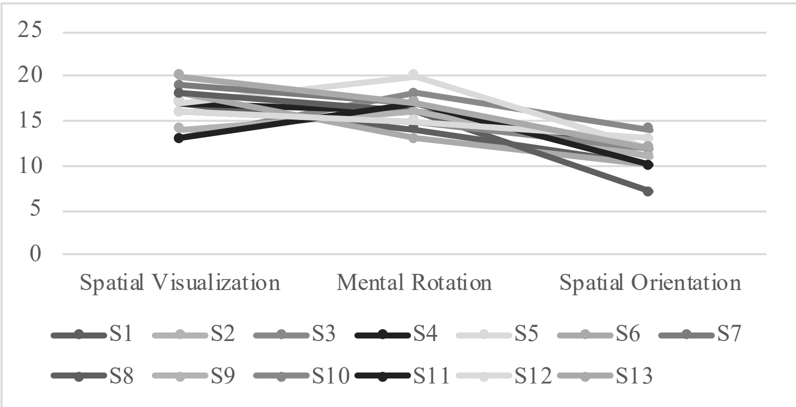


Figure 4

High ability student score



Based on these results, the aspect of spatial visualization is the aspect that has the highest value compared to the other two aspects. The aspect of spatial orientation is the least value aspect. Then if the results are compared by grade, then the second-year participant excels at the spatial visualization aspect. On the other hand, third-year participants excel at aspects of mental rotation and spatial orientation.

The result of spatial reasoning ability classification found that 13 participants have high spatial reasoning ability. Then if reclassified based on the value on each aspect then obtained as in the following Figure 3.

Based on Figure 4, subjects with the highest scores on spatial visualization are S2 and S13. The highest score in mental rotation is S5. Then on the spatial orientation is S3. The four subjects were selected and facilitated to conduct learning in primary school.

At the time of learning, the four subjects were observed to see whether the spatial reasoning they used was used in the lesson. Observations are based on three aspects of spatial reasoning. Learning is doing in grade V on mathematics subject with material of cube and cuboid.

The observations made on subjects based on the spatial visualization aspect indicate many learning activities that reflect spatial reasoning. Aspects of spatial visualization are widely used in drawing and showing the properties of cubes and cuboid. In this case the subject describes the cube on the board. Cube drawings made on the blackboard are ribs drawn with dashed lines. After being confirmed by interview, the subject stated that the ribs were not visible from the front. Therefore, it needs to be drawn with dashed lines. This suggests that spatial visualization ability is used in explaining it.

Then still on the aspect of spatial visualization, in the explanation of the cube net, the subject explains the process of opening the cube into a variety of nets. The explanation made by the subject shows the existence of the construction process from waking the room into webs and vice versa. The most important part of what the subject explains to the student is the explanation of the various forms of cube nets.

Furthermore, the observations on the mental rotation aspect showed quite unique symptoms. Drawing up solids ie cubes and cuboid, the subject describes it in various positions. Usually in drawing cuboid, both the pictures contained in the book and the usual draw by the teacher in general is always horizontal. In this case, the subject draws up the space in a vertical, horizontal, or diagonal position. It shows that however the position of the waking space, the concept will not change. The images presented by the subject are drawn clearly and very well. The subject's creativity is really shown in this case.

In the aspect of spatial orientation, the results obtained cannot be separated from the mental rotation and spatial visualization aspects. When describing the properties of the cube through the created image, the subject explains that the six sides of the cube are square even in the drawings made on the board all the sides are not square. This shows that the subject views the cube not from what is seen in the picture but looks at the cube side from the front, back, left, right, up, and down. This has been confirmed during interviews that show the subject views the image from a variety of perspectives. The same thing is done when explaining the cuboid. Uniquely, the learning instrument created and given to students to provide a question that corresponds to the aspect of spatial orientation.

Based on findings on learning by subjects with high spatial reasoning abilities, the phenomenon of using spatial reasoning exists in learning. Spatial reasoning is mostly used when explaining the concept of using spatial objects. Therefore, the existence of spatial reasoning in learning can be shown.

DISCUSSIONS

This study aims to show the existence of the spatial reasoning of preservice elementary school teachers in learning mathematics. The existence of spatial reasoning in learning is very important as a form of spatial reasoning connection with mathematics (Joh, 2016; Mulligan et al., 2017). By showing the existence of spatial reasoning in learning, the findings in this study can serve as the basis for the integration of spatial reasoning in learning.

The form of existence of spatial reasoning in mathematics learning is the process of preservice teachers in explaining the concept of mathematics. While explanations are used every day in the mathematics classroom (Levenson, Tsamir, & Tirosh, 2010). The explanations made by preservice teachers in the classroom proved to be charged with spatial reasoning. Furthermore, explanations in the classroom contain spatial visualization, mental rotation, and spatial orientation.

Explaining is an activity in which teachers communicate subject-matter content to students (Charalambous, Hill, & Ball, 2011; Stein & Kucan, 2010; Subramaniam & Esprivalo Harrell, 2013). The explanation can be a description of concepts and procedures (Stein & Kucan, 2010). With an explanation of charged spatial reasoning, it will provide the potential for improving students' mathematical performance and spatial reasoning abilities.

The results of this study show the various activities undertaken by teachers in learning mathematics. These activities are activities that show the use of spatial reasoning in learning. Activities that correspond to spatial reasoning on spatial visualization aspects allow teachers to be able to give an image of an object about a particular situation. This corresponds to the training undertaken by Lowrie et al., (2017). The difference is that Lowrie designed his training outside of mathematics learning and did not pay attention to the curriculum. The next difference is that Lowrie directly develops the students' spatial reasoning.

Furthermore, this study shows that without intervention, teachers can teach spatial reasoning through the content provided by the curriculum. This is very likely to be done in the 2013 curriculum in Indonesia. On the other hand, this study complements research based on spatial reasoning interventions. Spatial reasoning is intervened through an activity such as arranging blocks and viewing perspectives (Casey et al., 2008; Kurtulus & Yolcu, 2013; Peng & Sollervall, 2014; Pradana, Sa'dijah, Sulandra, Sudirman, & Sholikhah, 2020), using Cabri 3D software (Basham &

Kotrlik, 2008; Güven & Kosa, 2008; Hartatiana, Darhim, & Nurlaelah, 2017) or origami instruction (Akayuure, Asiedu-Addo, & Alebna, 2016). This means that spatial reasoning can be integrated not only through intervention but also through the content available in the mathematics curriculum.

Spatial reasoning is very potential to improve students' mathematical performance (Cheng & Mix, 2014; Hawes, Moss, Caswell, & Poliszczuk, 2015; Lowrie et al., 2017; Newcombe, 2013; Rabab'h & Veloo, 2015). Based on this situation, if spatial reasoning can be routinely used by teachers in learning, then the potential that the learning is done can make students' math performance better. Besides, the mathematical performance of the students' own spatial reasoning abilities will also develop. With the development of students' spatial reasoning, then teachers can help students have the potential to succeed in both mathematics and STEM (Gilligan, Flouri, & Farran, 2017; Hawes et al., 2015; Newcombe, 2013).

This study also provides an overview of a cycle of spatial reasoning abilities. It has the potential to make students' mathematical skills and spatial reasoning better. When the student graduates and then becomes a teacher, with his spatial reasoning ability will do the same to his or her students someday. This cycle is something that theoretically needs to be developed further.

Research to develop and improve spatial reasoning has been widely practiced (Francis, Khan, & Davis, 2016; Hallowell, Okamoto, Romo, & La Joy, 2015; Lowrie et al., 2017; Stevenson & Gernsbacher, 2013), but still have not seen from the teacher's perspective which then leads to the cycle. This study shows that spatial reasoning is used in learning that is compatible with the mathematics curriculum. Therefore, the potential to lead to a cycle of spatial reasoning is likely to be enormous.

CONCLUSIONS

The results of this study indicate the existence of spatial reasoning in mathematics learning by pre-service teachers. This is demonstrated by using spatial reasoning by pre-service teachers with high spatial reasoning. The three aspects of spatial reasoning are spatial visualization, mental rotation, and spatial orientation, which can be integrated through learning mathematics. Spatial reasoning activities in the classroom are more likely to occur when the pre-service teacher explains. The explanation made by the pre-service teacher is an explanation of the concept of mathematics. Thus, mathematical content is very much in line with spatial reasoning, especially in geometry. Then, it becomes the basis for cultivating spatial reasoning in mathematics learning.

This research has also connected with previous research in which mathematical performance can be enhanced by training spatial reasoning. Integrating spatial reasoning in learning can make students successful in many fields, especially in the field of STEM. Further research can develop a learning model based on spatial reasoning in learning. In addition, the field of mathematics under study can be developed in other mathematical fields, such as algebra.

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