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Mathematical Spatial Ability and Geometry Ability: A Correlation Study

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Abstract:
Geometry is a mathematical content that requires students' spatial reasoning. The difficulty experienced by students in solving geometry problems is because students do not understand spatiality and spatial visualization of three-dimensional shapes presented in two dimensions. This research is quantitative research with the main data of XII grade students. The selection of subjects is based on the three-dimensional material taught at the XII grade level. The purpose of this research is as an initial observation of the spatial correlation with students' ability to solve three-dimensional problems. Spatial indicators in this study include spatial visualization, spatial orientation and spatial relations. The material of the third dimension is about the position of the point to the point, line and plane, the position of the line to the line and plane, the position of the plane to the plane and the distance of the line to the line and plane. The research method used is assisted by Ms.Excel to determine the correlation between spatial abilities with geometry skills of students and based on the calculation results obtained it can be concluded that there is a correlation between the spatial ability of students to the geometry ability of students in solving the three-dimensional material.

Keywords: Spatial Ability, Third Dimension, Geometry, Mathematics Learning.

1. Introduction

Mathematics is dubbed as the mother of science. The nickname is because almost every aspect of human life requires mathematics. This is why mathematics is a compulsory subject in schools taught from elementary school to high school. However, not a few students find mathematics difficult because the objects studied are abstract so that mathematics cannot only be learned by rote but must be understood conceptually. Council of Teachers of Mathematics (2000) explains that mathematics contains the content of numbers and operations, geometry, measurement, data analysis and probability. While the process standards in learning mathematics consist of problem solving, reasoning and proof, communication, connection and representation. (Council of Teachers of Mathematics, 2000).

Geometry is a branch of mathematics that has a special position in learning mathematics at school and fulfils the indicators of school mathematics. Geometry discusses fields, spaces, shapes, lines, distances and so on. Geometry learning standards are can analyze the characteristics and properties of two-dimensional and three-dimensional spatial shapes, determine distance and location, apply transformations, and spatial reasoning in solving these problems (*Kemendikbud*, 2018). Understanding geometry at the previous level affects the material being taught. This is because mathematics is hierarchical so that to learn mathematics must master the earlier material. The third dimension is geometry taught in class XII. The material taught in the third dimension focuses on building blocks, cubes and pyramids. According to Alexander (2007), "A cube is a right square prism whose edges are congruent" which means a cube is a square prism that has congruent ribs while a beam is a medium rectangular upright prism. A quadrilateral pyramid is a pyramid with flat polygons with congruent upright sides (Alexander, 2007). The third

dimension material taught in class XII studies the position of points to points, lines and planes, the position of lines to lines and planes, the position of the plane to the plane, the distance of lines to lines and planes.

Students with high spatial ability have a high spatial imagination so that spatial ability is needed to solve three-dimensional problems. Based on observations made on several class XII students, the difficulty in the three dimensions material is to represent the sentence in the problem into the form of a picture. This is because the object being discussed should be in three-dimensional space but students represent it as a two-dimensional building so that students need the ability to imagine to solve third-dimensional problems. Another condition that occurs is that spatial tests are usually given as preparation for university entrance so that there are still many students who feel unfamiliar with it. Contrary to the statement in (The National Academies Press, 2005)that spatial ability should be trained at all levels of education. According to Lohman (1993), spatial ability is the ability to generate, maintain, retrieve and transform well-structured visual images. The National Academies Press (2005) states that spatial thinking is a cognitive collection that aims to change, combine or operate on the concept of space. The involvement of the concept of space in spatial thinking ability is a differentiator among other thinking abilities. From several explanations of experts and several sources, it can be concluded that spatial ability consists of three elements which are explained as follows:

1) Spatial Orientation

   According to Lohman (1993) suggests that spatial orientation is the ability of students to remain unconfused due to changing orientation more precisely when spatial configuration occurs. Meanwhile, according to Maier (1998) states that spatial orientation is the ability to orient oneself physically or mentally in space which means that spatial orientation is the ability to adjust physically or mentally in space. From the opinions of the two experts, the definition of spatial orientation can be simplified as the ability to understand the state of objects and be able to identify objects even though their position is changed.

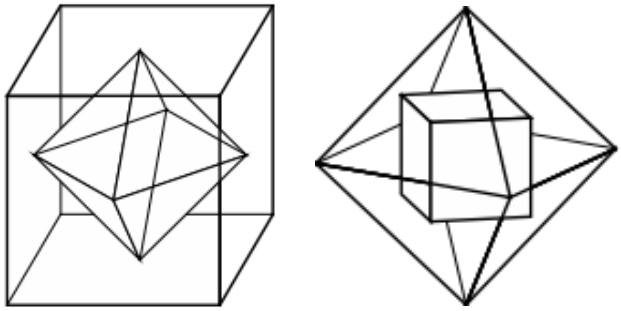


Image 1 : Spatial Orientation
Source: Maier (1998)

2) Spatial Visualisation

   According to Lohman (1993) says that “spatial visualisation is the ability to comprehend imaginary movement in a three-dimensional space or the ability to manipulate objects in the imagination” which means spatial visualisation is the ability to understand imaginary movement in three-dimensional space or the ability to manipulate objects in the imagination. Meanwhile, according to Maier (1998) states that "Comprise the ability to visualise a configuration in which there is movement or displacement among (internal) parts of the configuration", which means it includes the ability to visualise *a* configuration in which there is movement or displacement among (internal) parts of the configuration. Based on the opinions of the two experts, it can be concluded that spatial visualisation is the ability to imagine objects visually or the ability to manipulate objects in the imagination. As well as being able to provide a picture of the object after moving the position and changing its shape.

3) Spatial Relation

According to Lohman (1993) suggests that "spatial relation is defined as the ability to mentally rotate a spatial object as a whole fast and correctly" which means that spatial relation is the mental ability to rotate spatial objects as quickly as possible correctly. Meanwhile, according to Maier (1998) argues that "spatial relation means the ability to comperhend the spatial configuration of objects or parts of an object and their relation to each other" which means spatial relation means the ability to understand the arrangement of an object or its parts and *their* relation to others. Based on the opinions of the two experts, it can be concluded that spatial relations are the ability to understand the parts of an object, the arrangement of an object and understand the relationship between these parts correctly.

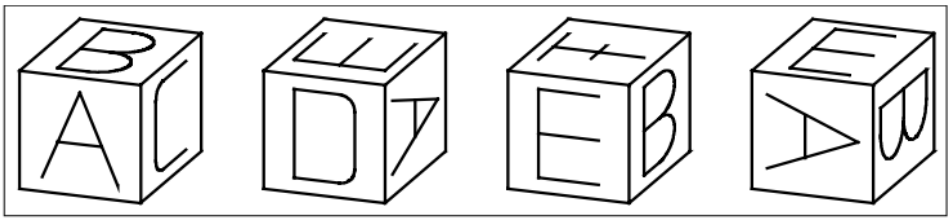


Image 2 : Spatial Relationship
Source: Maier (1998)

Spatial thinking requires knowledge of space, representation of relationships between spaces and reasoning to calculate distances between spaces. Geometry is a branch of mathematics that studies space. Since kindergarten, children have been introduced to very simple geometry such as squares, circles, triangles and so on. Then, at the elementary school level, children are familiar with the properties of spatial shapes and calculations that are still simple until at the high school level, the geometry taught starts to be complex. Therefore, spatial abilities need to be trained to hone students' spatial imagination so that it is hoped that students will no longer have difficulty representing the third dimension. This opinion is reinforced by the results of research Hannafin et al. (2008) which supports the hypothesis that students with spatial abilities are more likely to be able to represent the third dimension which supports the hypothesis that students with high spatial ability tend to outperform students with low spatial ability in solving geometry problems. Kim & Kwon, (2023) also presented the results of their research that individuals with better spatial reasoning skills tend to have better performance in solving geometry problems.

Based on the background described above, the author conducted a correlation study of students' mathematical spatial abilities with geometry skills in the three dimensions material. This study aims to understand how the correlation of students' spatial abilities to geometry skills as an initial observation for further research on media development to improve students' spatial abilities in solving three-dimensional materials.

2. Research Methods

Data collection method is an important stage in research activities. The data collection method used affects the validity of the data. Data collection is useful for transforming facts into data which are then processed and analyzed to achieve research objectives (Djaali, 2020). This research is quantitative research with Ms. Excel which aims to find out the correlation between students' spatial abilities with geometry skills on three-dimensional material. The subjects of this study were XII grade students. Data collection methods used in this study are questionnaires and written tests. The data analysis methods used are (1) data analysis of the results of spatial ability test questions, (2) data analysis of the results of the test questions of dimension 3, (3) analysis of questionnaire data (4) presentation of data (5) drawing conclusions. Data collection in this study was conducted *online* through *google form* which was conducted from October-November 2023. The data collection method is as follows:

1) Observation

Observations were conducted to determine the initial condition of students' spatial ability and geometry ability in the third dimension material. Observations were carried out *online* through *google form* distributed to students of class XII. Data collection on the *gform* consists of four parts including (1) the respondent's biodata, (2) observation of students' spatial abilities by giving 15 spatial questions (3) observation of students' geometry skills in the third dimension presented in three questions (4) a questionnaire about the respondent's opinion which consists of four questions including, do you think the spatial problem is difficult? Do you agree if the spatial problem is given before the third dimension material? Give your reasons, which part do you think is easy in the material of the third dimension, which part do you think is difficult in the material of the third dimension?

2) Test

The test questions were given as an initial step to find out the students' abilities and as material for data analysis which aims to find out the correlation of students' spatial abilities to the students' ability to solve three-dimensional problems.

3) Correlation Test

The correlation test in this study uses One way annova. If $p-value<0,05$ then H_0 is rejected which means there is a correlation between spatial ability and geometry ability of students

The researcher becomes the main instrument of the research. Researchers determine the success of the research conducted. Therefore, the researcher must be able to find the right data source so that the research results are in accordance with the research objectives. As the main instrument, the researcher is in charge of planning research, carrying out research, analysing data, interpreting data, writing research reports and concluding research results. Data analysis is the activity of classifying and processing data to obtain final results that are in accordance with the research problem. This activity helps researchers in determining the final conclusion and information that is clear and can be accounted for.

3. Results and Discussion

3.1 Students' Spatial Ability

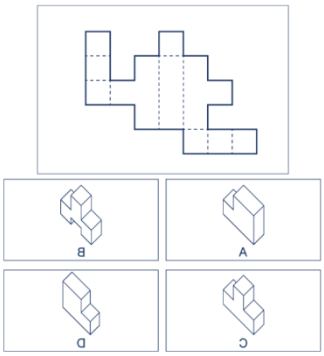
Spatial ability in this study can be seen based on the results of student answers in Table 1. Almost all students made mistakes in numbers 1,8,10,11. Question number 1 relates to spatial visualization, which is converting two-dimensional shapes into three dimensions. Spatial visualization requires a very high level of spatiality. In questions number 8 and 11 are representations of spatial relations problems. In this problem students must know the relationships or interrelationships between images. In question number 10, spatial visuals, students are trained to be quick in seeing and thinking so that they can understand the continuation of the images presented. In question number 13, spatial relations, students choose a logical relationship in determining the next picture based on the sequence of images presented. Errors experienced by students may be a lack of accuracy or students experience confusion in determining answers. In solving spatial problems students do not have to have special talents but by practicing regularly until they become accustomed to it.

Table 1 : Results of Students' Spatial Answers

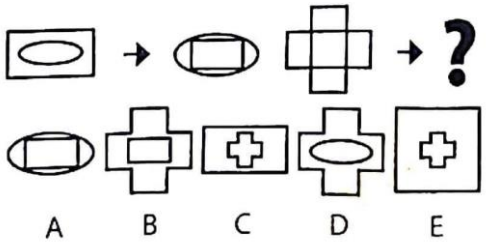
Question	**Students**					
No.	**1**	**2**	**3**	**4**	**5**	**6**
1.	**S**	**S**	**S**	**S**	**S**	**S**
2.	S	B	B	B	B	S
3	S	B	B	B	B	B
4	S	B	B	B	B	B
5	B	B	B	B	B	S
6	B	B	B	B	B	B
7	S	B	B	B	B	B

Question No.	Students					
	1	**2**	**3**	**4**	**5**	**6**
8	**S**	**S**	**S**	**S**	**S**	**S**
9	S	B	B	B	B	S
10	**S**	**S**	**S**	**S**	**S**	**S**
11	**S**	**S**	**S**	**S**	**S**	**S**
12	S	B	B	B	B	S
13	**S**	**S**	**S**	**S**	**S**	**S**
14	B	B	B	B	B	S
15	B	B	B	B	B	S
Total Correct	4	10	10	10	10	4

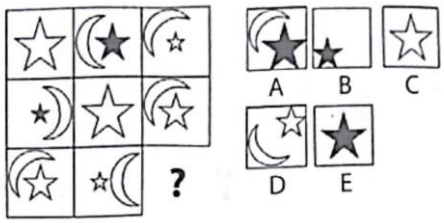
Here are the spatial questions that the majority of students got wrong.



(a)



(b)



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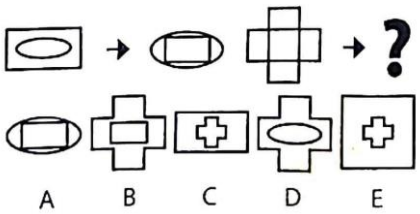
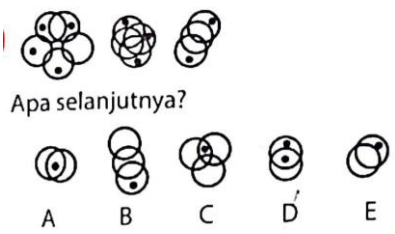


(d)



(e)

Image 3 : (a) Problem number 1, (b) Problem number 8, (c) Problem number 10, (d) Problem number 11, (e) Problem number 13.
Source : (a) Source: www.assesmentday.co.uk, (b)-(d) *(Smart Media R&D Team, 2017)*

3.2 At rrectly. If viewed further, it does not appear that students with high spatial abilities can better solve the three

dimensions problem. Thus, this study is not in line with research conducted by Mahfuddin & Caswita, (2021) that students with high spatial abilities are able to solve all stages of geometry problem solving. Many factors influence these differences. Based on the results of the questionnaire, students find it difficult when determining the distance in the part of the building space both the distance between points, points to the plane and the plane to the plane. Another influencing factor is the readiness and psychology of students also affect the process of solving geometry problems. Research conducted by Pavlovicova & Zahorska (2015) stated that students' attitudes towards geometry affect students' geometry learning outcomes. The cause of student errors in working on geometry also agrees with research conducted by (Ridha et al., 2023) that the main factor causing errors in solving geometry problems because students lack mastery in seeing the spatial so it is recommended that teachers train students' spatial visualization skills before teaching three-dimensional material. Research conducted by Anwar et al. stated that students' learning styles also affect students' spatial abilities. Research conducted by (Tikhomirova, 2017) showed differences in spatial abilities in groups of students who have high, low and medium mathematics abilities and gender cause differences in spatial test results. In such a way, there is a need for further evaluation and research aimed at training and get students to solve geometry problems, especially three-dimensional material at the high school level.

Table 2 : Results of Student Answers on the Material of the Three Dimensions

Question No.	**Subject**					
	1	**2**	**3**	**4**	**5**	**6**
1	B	B	B	B	B	B
2.	S	S	S	S	S	B
3.	S	B	S	S	S	S
Total Correct	1	2	1	1	1	2

3.3 Correlation between Spatial Ability and Students' Geometry Ability

This study uses One way annova test to determine the correlation between spatial ability with geometry ability. Decision making if $p-value<\alpha(0,05)$ then H_0 is rejected which means there is a correlation between spatial ability with geometry skills of students. The following are the results of descriptive statistical calculations in Figure 4 and the results of the One way annova test in Figure 5.

Groups	*Count*	*Sum*	*Average*	*Variance*
Spasial	6	48	8	9,6
Dimensi Tiga	6	8	1,333333	0,266667

Image 4 : Descriptive statistics test results

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	133,3333	1	133,3333	27,02703	0,000402	4,9646
Within Groups	49,33333	10	4,933333			
Total	182,6667	11				

Figure 5: One way annova test results

Based on the results of the calculation obtained $p-value=0,000402<0,05$ then H_0 rejected means there is a correlation between spatial abilities with geometry skills of students. This agrees with research conducted by Möhring et al., (2021) that students' spatial skills have an impact on students' understanding of mathematics so that spatial reasoning has an important role in students' understanding of mathematics. The results of this study are also in line with research conducted by Yu et al., (2022) that spatial reasoning is

significantly related to geometry problem solving. In such a way, this study believes that spatial reasoning is an important factor that predicts an improvement in students' mathematics problem solving. Research conducted by Fujita et al. (2017) shows that students' geometric thinking is influenced by the ability to manipulate representations and spatial reasoning effectively. Based on the questionnaire results, it also reinforces that students expect spatial tests and spatial problem exercises to be given before the third dimension material. This is because spatial trains students' spatial imagination without doing calculations. So that when students have entered the third dimension material, students are familiar with spatial visualisation, spatial relations and spatial orientation. This habit is expected to make it easier for students to solve third dimension problems. Research conducted by Dintarini et al., (2022) which focuses on case studies of students' spatial abilities including spatial visualisation, spatial orientation and spatial relations shows the results that each spatial indicator is related to certain geometry materials and suggests that spatial abilities need to be improved in mathematics learning so that students' geometry understanding is better.

4. Conclusion

This research is quantitative research with Ms. Excel which aims to find out the correlation between students' spatial ability and problem solving ability in the three dimensions material. The subjects of this research are students of class XII. The data collection methods used in this research are questionnaires and written tests. The data analysis methods used are (1) data analysis of the results of spatial ability test questions, (2) data analysis of the results of the three dimensions test questions (3) questionnaire data analysis (4) data presentation (5) conclusion drawing. Data collection in this study was conducted online through google form which was carried out from October to November 2023.

Spatial thinking requires knowledge of space, representation of relationships between spaces and reasoning to calculate distances between spaces. Geometry is a branch of mathematics that has a special position in learning mathematics at school and fulfils the indicators of school mathematics. Geometry discusses fields, spaces, shapes, lines, distances and so on. Students with high spatial abilities have a high spatial imagination so that spatial abilities are needed to solve three-dimensional problems.

Based on the calculation results obtained $p-value = 0,000402 < 0,05$ then H_0 rejected means there is a correlation between spatial ability with geometry skills of students. A*t Table 1*almost all students make mistakes in number 1, 8, 10, 11. In question number 1 is related to spatial visualization that is changing the shape of two dimensions into three dimensions. Spatial visualization requires a very high level of spatiality. In questions number 8 and 11 are representations of spatial relations problems. In this question students must know the relationships or interrelationships between images. In question number 10, spatial visual, students are trained to be quick in seeing and thinking so that they can understand the continuation of the image presented. In question number 13, spatial relations, students choose a logical relationship in determining the next picture based on the sequence of images presented. It can be concluded that students still need to be accustomed to spatial visualization because to perform calculations in the third dimension, the first step used by students is to observe visually and then represent the problem verbally in the form of two-dimensional images and finally perform calculations. On Table 2, we can see that out of three questions, the average student answered one question correctly. If viewed further, it does not appear that students with high spatial abilities can better solve three-dimensional problems. The influencing factors are not only students' cognitive problems but learning styles, gender and students' attitudes towards geometry itself.

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