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Profile of Spatial Ability of High School Students When Solving Geometry Problems

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Abstract

Learning geometry began in elementary school and continued through high school, as well as at more advanced levels in the area of interest of higher education. This is because studying geometry can enhance students' problem-solving skills and mathematical reasoning. Prioritized in geometry are the acquisition of spatial reasoning skills and an understanding of geometrical shapes and properties. This research aims to describe the spatial abilities of high school students in solving geometry problems. This study used qualitative research methods using descriptive design. The research subjects in this study were ten grade students in a senior high school in Aceh, Indonesia, consisting of three subjects with high, medium and low geometry abilities. Data collection techniques used were tests and interviews. The instruments in this study were geometric ability tests, spatial ability tests and interview guidelines. Data analysis techniques use data analysis techniques; data reduction, data display and draw a conclusion. The results of the study show that the spatial ability profile of students in the high and medium categories in solving geometry problems is that they have good abilities in showing correct perception of the position of geometric objects; have good ability to show correct perception of the shape of a geometric object. The low category students have good abilities in spatial perception but have poor abilities in visualization abilities. Students with high, medium and low abilities in solving geometry problems have good abilities in demonstrating mental rotation abilities.

Keywords: Geometry, High School Students, Profile, Spatial Ability.

Introduction

The features and relationships between points, lines, planes, and spaces are covered in one of the mathematical courses known as geometry (Akıncı & Genç, 2020; Bergstrom & Zhang, 2016). Learning geometry began in elementary school and continued through high school, as well as at more advanced levels in the area of interest of higher education. The study of geometry is important for mathematics. This is because geometry teaches students how to analyze and solve complex problems in a logical and structured manner (Kaufmann, 2011). Through geometry, students learn to think abstractly and logically, developing the ability to prove and understand mathematical concepts (Septia et al., 2017). Students who study geometry should be able to examine the features of two and three-dimensional geometries and draw links between them. They should also be able to employ visualization, spatial reasoning, and geometry modelling to solve mathematical problems (NCTM, 2000). Even though geometry is relatively difficult mathematical material (Adolphus, 2011; Cesaria & Herman, 2019; Soedjadi, 1991), a good understanding of geometric concepts can be a strong basis for growing students' interest in studying more difficult and extensive mathematics (Jones, 2003).

The development of spatial reasoning abilities and knowledge of geometrical shapes and attributes are prioritized in geometry education (Karakırık, 2011). It is believed that spatial ability is a crucial requirement for solving geometry problems. High performance in geometry has often been correlated with high levels of spatial ability (Panaoura et al., 2007). The process of creating a two-or three-dimensional geometric figure in space mentally and consider many viewpoints. Therefore, in geometrical thinking, spatial visualization is the most crucial component (Pujawan et al., 2020; Yenilmez & Ozlem, 2015). This is supported by Tessema's research (Tessema, 2018) which stated that spatial ability has a major impact on geometric ability and influences approximately 29.90% of the variables that define geometric ability in Ethiopian primary schools.

The capacity to create, organize, retrieve, and alter coherent visual pictures is referred to as spatial ability. It is not a single construct. In fact, there are various spatial skills which are each stressing a distinct component of the generation, storing, retrieval, and alteration of images (Lohman, 1993). In general, the ability to create and control mental images in the mind is a component of spatial ability (McGee, 1979). According to Lohman and McGee, the ability to create these images and generate information about them collectively constitutes spatial ability. Additionally, it involves having the capacity to actively interact with images besides to simply storing and retrieving them from memory (Dilling & Vogler, 2021). Drawing shapes, manipulating items in an abstract space, and having spatial thinking skills are all important components of spatial intelligence (Aziz et al., 2017). In terms of spatial ability, Maier identifies five elements; spatial perception, visualization, mental rotation, spatial relation, and spatial orientation (Maier, 1996). Maier constructed these categories by summarizing and examining various essential structural ideas of spatial ability (Dilling & Vogler, 2021).

Spatial abilities refer to skills in representing, transforming, generating, and remembering symbolic non-linguistic information. Three types of spatial abilities; spatial perception, spatial visualization, and mental rotation were established by Linn and Petersen (1985). Spatial perception is the ability to distinguish lines, horizontal planes and vertical planes in spatial shapes. Spatial perception ability also consists of the ability to identify vertical and horizontal objects even though the position of the object is manipulated. Spatial visualization is the ability to visualize or see the composition of an object after its position and shape have been manipulated. Spatial visualization abilities also include the ability to see a three-dimensional object from one point of view and another. Mental rotation is the ability to describe objects in two and three dimensions after rotation. Mental rotation ability includes the ability to rotate plane shapes and spatial shapes and imagine the rotation of these shapes correctly (Linn & Petersen, 1985). Lohman argues that there are three main factors of spatial ability; spatial visualization, spatial orientation, and speeded rotation (Lohman, 1993). From the several opinions above regarding the meaning of spatial ability, it can be concluded that spatial ability is a mental ability related to understanding, manipulating, rotating and visual relationships which is in accordance with the indicators by Linn and Petersen. This research uses three indicators of spatial ability proposed by Linn and Petersen, spatial perception, spatial visualization, and mental rotation.

The most prevalent theoretical approach is that spatial representations strengthen mathematical thinking (Mix et al., 2021). Mathematical issues frequently require the processing of spatial information, from mental number lines to geometrical figures (Rittle-

Johnson et al., 2018). Students that have good spatial skills perform much better in mathematics (Syahputra, 2013). Learning geometry can help students develop their spatial abilities (Trimurtini et al., 2021). An individual's capacity to perceive the visual world clearly and to anticipate how different geometric things will interact is referred to as their spatial ability (Akayuure et al., 2016). It is clear that spatial ability is important for students given the context of mathematics, especially geometry (Rohmah et al., 2021). From the statements that have been mentioned, it is clear that there is a close relationship between spatial abilities and geometry learning.

However, a lot of students have trouble visualizing two-dimensional or three-dimensional shapes, which makes it difficult for them to comprehend the notions of volume and surface area in general. Additionally, a lot of students struggle to illustrate a three-dimensional object on a flat surface (Septia et al., 2017). Since Indonesia has participated in TIMSS, the geometry subject area has seen the most significant decrease in scores (Suwito, 2018). This shows that compared to other content domains, the percentage of errors when performing geometry problems is higher. An example of a geometry subject domain problem from TIMSS 2011 with the greatest number of errors committed by Indonesian students is shown in Figure 1 (Maulana et al., 2023).

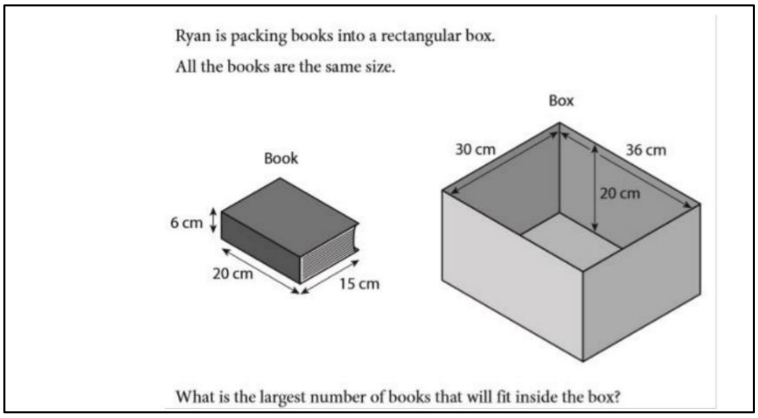


Figure 1. An example of a problem where Indonesian students made the most mistakes.

High levels of geometry abstraction and students' capacity for abstract object representation were the reason for the problems with geometry in schools (Ningsih et al., 2021). According to other research findings, students with low spatial intelligence make the most errors because they have poor visual skills (Riastuti et al., 2017). The other study stated that: (1) level 2 (abstraction) students exhibit spatial abilities that include vision, spatial orientation, and spatial rotation. (2) students with level 1 (analysis) have spatial skills that include spatial orientation. (3) students at level 0 (visualization) lack spatial skills (Aulia et al., 2023). Therefore, it is necessary to conduct research to describe students' spatial abilities in solving geometry problems. In this study, the researcher aims to describe the spatial abilities of high school students in solving geometry problems.

Methods

This research used qualitative research methods using descriptive design. In descriptive designs, the researcher explains the collective experiences and aims to ascertain or comprehend the participants' points of view, with a focus on how participants interpret a situation (Merriam, 2002). The participants of this study were ten grade students in a private senior high school in

Aceh, Indonesia. The instruments used in this study were written tests and interviews. The written test consists of a geometry ability test and a spatial ability test. The geometric ability test is used to obtain a classification of students' geometric abilities in the form of levels of students' geometric abilities. The questions used in the geometry test are questions adopted from the National Examination (UN) which relate to basic geometry material; square, rectangle, cube and cuboid. The spatial ability test is used to describe the profile of students' spatial abilities. Validation of the spatial ability test used the content validity of the Gregory test (Gregory, 2011) with two experts. From the results of the validity test, the results were 83.3%, so the validity criteria showed very high criteria. Additionally, the content reliability will be determined by the significance of the two experts and will be expressed as the content's internal consistency coefficient. The reliability estimation result is 0.782 which states that the instrument is reliable. The interview guide instrument is an instrument used to help gather information about the profile of students' spatial abilities. Validation of the interview guide also used the content validity of the Gregory test which resulted in 91,7%, thus indicating that the interview guide in this study was valid.

Furthermore, we selected three students in high, medium, and low abilities from 17 students who took geometry tests. Grouping geometric abilities based on geometry test results refers to Ma'sum's opinion (Khoirudin et al., 2017) which is shown in Table 1.

Table 1
Interval Values for Each Category

Interval Values	Category
≤ 40	Low
41 - 70	Medium
≥ 71	High

From there, they are assigned to spatial ability tests and interviews. The reason the researchers gave the spatial ability test after the subjects completed the geometry test was because spatial ability is part of the geometric ability related to three-dimensional shapes (spatial shapes), and this spatial ability focuses on being able to correctly recognize an object or image and its parts. The interview method used was a semi-structured interview. Data analysis techniques use data analysis techniques proposed by Miles and Huberman, namely data reduction, data display and draw a conclusion (Miles et al., 2014). The research procedure in this study is shown in Figure 2.

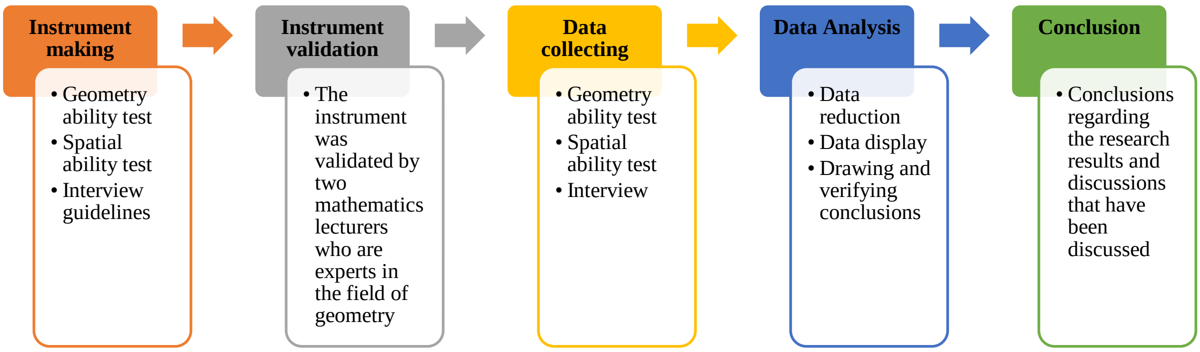
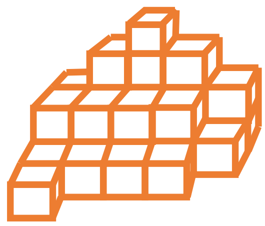
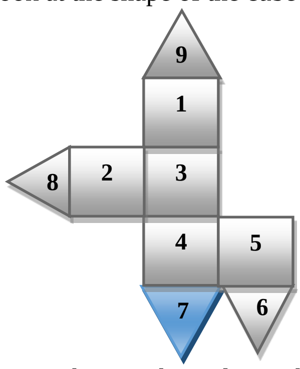
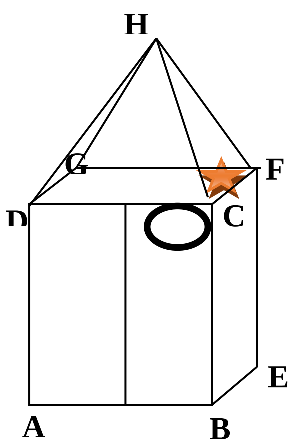


Figure 2. Research procedures.

The indicators used in this study are indicators of spatial ability adopted from spatial ability research (Azustiani, 2017; Hibatullah et al., 2020; Linn & Petersen, 1985a; Nurjanah & Juliana, 2020). Table 3 shows indicators and questions of spatial ability.

Table 3.
Indicators and Questions of Spatial Ability

No	Characteristics of Spatial Ability	Indicators	Questions
1.	*Spatial Perception*	• Students are able to show the correct perception of the position of geometric objects. • Students are able to demonstrate precise perception of the shape of a geometric object.	If you look at the pile of boxes from above, how will the shape of the image be formed?  (I. Ningsih & Haerudin, 2019)
2.	*Visualization*	• Students are able to solve problems related to objects whose position or shape has been manipulated. • Students are able to visualize or see the composition of an object after manipulating its position and shape.	Look at the shape of the cube net below!  It is known that side number 7 is the front of the pyramid, so draw the nets into geometric shapes and determine which number side is the base of the cube and name the opposite sides!
3.	*Mental rotation*	• Students are able to rotate a geometric shape and imagine the rotation of the geometric shape accurately. • Students are able to describe a three-dimensional shape after rotation.	A wooden box in the shape of a block with the following picture: 

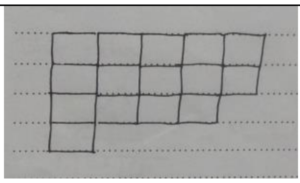
No	Characteristics of Spatial Ability	Indicators	Questions
			If the wooden block image is rotated to the right by 180°, the resulting image is...

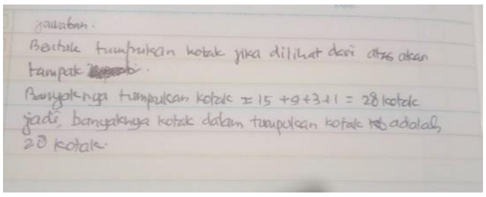
Results and Discussion

Based on the results of the geometry ability test, it was found that 3 subjects had different levels of geometry ability: high, medium and low. The following are some of the results of student work and interview results regarding the spatial abilities of students with low, medium and high abilities.

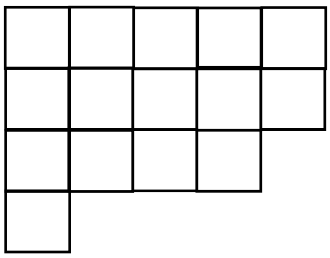
Findings from Subject AN for Problem Spatial Perception Indicator

Problem 1 is a problem related to spatial perception indicators. The following are the results of students' work on problem 1 on the spatial perception indicator.





Solution:



The shape of the pile of boxes when viewed from above will appear:

Number of piles of boxes = 15 + 9 + 3 + 1
= 28 boxes

So, the number of boxes in the pile of boxes is 28 boxes.

Figure 3. AN's answer with spatial perception indicator

The results of subject AN's interview excerpts in understanding problem spatial perception indicator are as follows.

Transcript 1. AN's interview excerpts in understanding problem spatial perception indicator

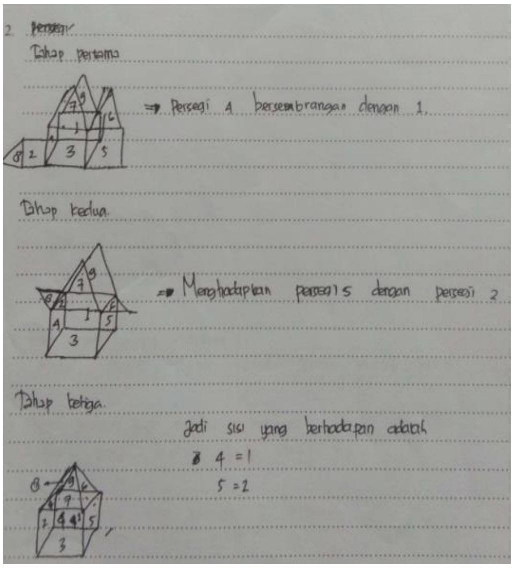
P	:	Do you still remember this problem?	
S	:	Still ma'am	
P	:	How do you solve it?	
S	:	I just counted, the number of boxes that are at the bottom ma'am, by counting the front part, then I drew the boxes according to the number of boxes in the picture, so the picture looks like this (while showing the picture).	SP1
P	:	Will the shape of the box be the same if seen from a different point of view? Like from the right or left side?	
S	:	It will be different ma'am	SP2
P	:	How many piles of boxes are in the picture? And how do you calculate it?	
S	:	(while counting) there are 28 boxes. The method is that I count at the very bottom left (while pointing at the picture), then I count to the back row, then when finished, I count the number of boxes on the right side until finished, then move up to the top, and so on until I count them all.	SP1

P : Are you still having trouble solving this problem?
S : Not anymore ma'am

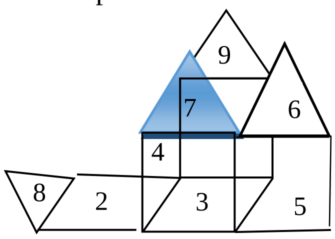
From the interview dialog and the student's work, information was obtained that the AN subject had good spatial perception skills. This is shown in a precise perception of the position of geometric objects. The subject correctly counted the number of boxes in the pile of boxes, namely 28 boxes. The subject counts the number of boxes with the first level at the bottom left extending backwards, when finished the subject counts the second left level extending backwards, and so on. The subject also has a good ability to show the right perception of the shape of a geometric object. This is shown when the subject correctly draws the shape of a stack of boxes seen from above and can correctly differentiate the shape of a stack of boxes when seen from the right and left sides.

Findings from Subject AN for Problem Spatial Visualization Indicators

Problem 2 is a problem related to visualization indicators. The following are the results of students' work on problem 2 on the visualization indicator.

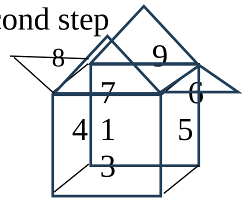


Solution:
First step



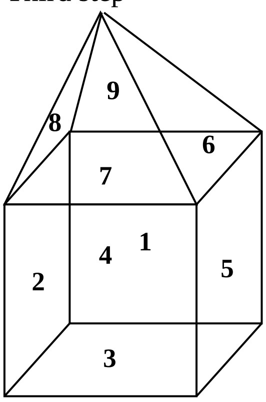
➡ The square 4 is opposite 1

Second step



➡ Facing the square 5 with square 2

Third step



So, the facing side is
4 = 1
5 = 2

Figure 4. AN's answer with spatial visualization indicator

The results of subject AN's interview excerpts in understanding problem spatial visualization indicator are as follows.

Transcript 2. AN's interview excerpts in understanding problem spatial visualization indicator

P	:	(Shows picture) Is this picture the nets of spatial shapes?	
S	:	Cubes and Prisms, right ma'am? This looks like pyramid.	
P	:	What kind of pyramid do you mean?	
S	:	A pyramid with a square base bu	
P	:	How many spaces are there formed?	
S	:	There are two, ma'am.	
P	:	In the picture, side number 7 is the front part of the pyramid, how do you build the parts into a cube and a pyramid?	
S	:	7 is the front of the pyramid, for example 3 is the base because 3 is in the middle of the side, so I raise sides number 4 and 1, I raise again 2 and 5, finally put sides number 7,9,8 and 6 together.	V2
P	:	Can only side number 3 become the base? Is there another side that could be a base?	
S	:	Yes ma'am, only side number 3 can be used as a base.	V1
P	:	Which sides are opposite?	
S	:	Side number 1 and side number 4, side number 2 and side number 5 and side number 9, side number 6 and side number 8	V2
P	:	Where is the position of the base?	
S	:	It is located below.	V1
P	:	Where is the position of the cover?	
S	:	The location is above.	V1
P	:	Do you think this kind of problem is difficult?	
S	:	Yes, because I don't know the steps to be taken and how to solve it.	
P	:	Did you have difficulty solving this problem?	
S	:	Yes ma'am, in the section on determining the reasons.	
P	:	What was the first step you took to solve the problem?	
S	:	I look at the picture, look for what is known, then look for the base.	

Based on the results of work and interviews with subject AN on problem spatial visualization indicator, information was obtained that the subject had good abilities in solving problems related to objects whose shape was manipulated. This is shown when the subject explains the side that is the base of the cube net, namely side number 3, and the subject also explains where the base and cover of the cube are correctly located. The subject is also good at visualizing or seeing the composition of an object after its position and shape have been manipulated. This was shown when the subject explained the sides to be folded first, namely side number 7 on the grounds that this side is known as the front of the pyramid. The two sides number 4 as the front side of the cube, the three sides number 1 and 9 as the back side of the cube and the back of the pyramid, the four sides number 2 and 8 as the right side of the cube and the pyramid and finally the sides number 5 and 6 as the left side of the cube and pyramid. The subject also explains the sides that are opposite each other, namely sides 4 → 1, 2 → 5, 7 → 9, and 8 → 6.

Findings from Subject AN for Problem Spatial Mental Rotation Indicator

Problem 3 is a problem related to mental rotation indicators. The following are the results of students' work on question number 3 on the mental rotation indicator.

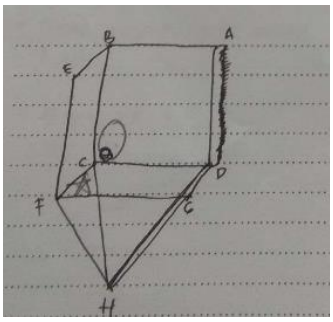


Figure 5. AN's answer with spatial mental rotation indicator

The following are the results of interview excerpts from subject AN's interview in understanding the following questions.

Transcript 3. AN's interview excerpts in understanding problem mental rotation indicator

P	:	For example, rotate it to the right by 180˚. This is often seen in the direction of rotation being turned to the right. Do you know?	
S	:	It seems clockwise, ma'am	
P	:	What if counterclockwise?	
S	:	Rotate it to the left, ma'am	
P	:	How is it said to be 90˚?	
S	:	$\frac{1}{4}$ of the circle rotation ma'am	
P	:	In this section it says rotate 180˚, so how much will it rotate?	
S	:	$\frac{1}{2}$ of the circle rotation ma'am	
P	:	After you turn it, what sign will change?	
S	:	Cube and pyramid shapes and some signs such as stars and circles.	MR1
P	:	What are the shapes of the space shapes and signs after being rotated 180˚?	
S	:	The pyramid is at the bottom, the cube is at the top, the circle mark moves to corner C, bottom left. The star sign has moved to the left corner of F	MR1
P	:	In question number 3, are you having difficulty?	
S	:	Yes, I have difficulty placing the signs	
P	:	If I add 1 more sign, will you experience difficulties too?	
S	:	No ma'am	

Based on the results of work and interviews with subject AN, information was obtained that the subject had good abilities in rotating a spatial shape and imagining the rotation of the spatial shape correctly. This is shown when the subject knows the direction of rotation to the right (clockwise) and the amount of rotation (180˚) in the existing spatial shape. The subject also has good abilities in describing three-dimensional shapes after rotation. This is shown when the subject draws a shape that has been rotated in the right direction (clockwise) and the angle is large (180˚) and the subject also mentions signs that have moved from the previous position, such as the pyramid moving down, the cube moving upwards, then the round sign moves to the left corner C and the star sign moves to the bottom left corner F.

Findings from Subject FU for Problem Spatial Perception Indicator

The following are the results of students' work on problem 1 on the spatial perception indicator.

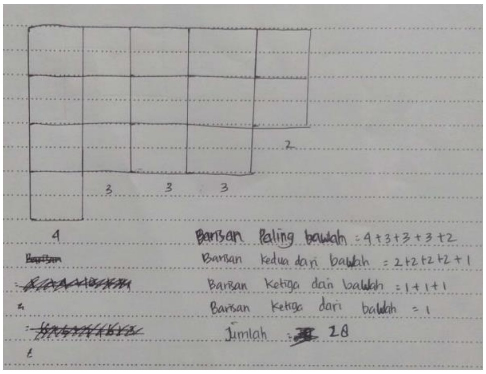
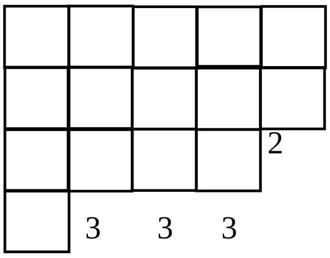
	Solution:  The bottom row = 4 + 3 + 3 + 2 The second row from bottom= 2 + 2 + 2 + 2 + 1 The third row from the bottom = 1 + 1 + 1 The third row from the bottom = 1 Total = 28

Figure 6. FU’s answer with spatial perception indicator

The results of the FU subject interview excerpts in understanding problem spatial perception indicator are as follows.

Transcript 4. FU's interview excerpts in understanding problem spatial perception indicator

P	:	How do you solve this problem?	
S	:	(*think for a moment*) I read the problem several times until I understood it. Then, I tried to rotate the image in the question. I can't imagine the shape of the picture. Then I tried to make blocks out of paper and I arranged the paper blocks according to the picture in the problem. Furthermore, I can see the image from above, then the image is formed. In addition, I can see the shape of the pile from above and can also see the shape of the stack from all angles.	SP2
P	:	Will the pile of boxes have the same shape when viewed from the right and left side?	
S	:	No, it's not the same ma'am	SP2
P	:	How many boxes are there in the pile?	
S	:	28 boxes ma'am	SP1
P	:	In working on this problem, do you have any difficulties?	
S	:	Yes, I'm having trouble.	
P	:	How do you deal with that difficulty?	
S	:	I read the questions several times until I understood. Then, I rotated the paper. However, I haven't found a solution yet, so I tried using a block that I made from paper, then I stacked the paper blocks according to the picture in the problem. So, I found this image form (while showing image).	

Based on the results of work and interviews with FU subjects in problem spatial perception indicator, information was obtained that the subjects had good abilities in showing correct perception of the position of geometric objects. This is shown when the subject correctly counts the number of boxes in the stack. The subject has good abilities in showing precise perception of the shape of a geometric object. This is shown when the subject correctly draws the shape of a stack of boxes seen from above and can differentiate the shape of a stack of boxes when seen from the right and left sides, with the help of blocks made of paper and arranged like the stack of boxes in the question.

Findings from Subject FU for Problem Spatial Visualization Indicator

The following are the results of students' work on problem 2 on the visualization indicator.

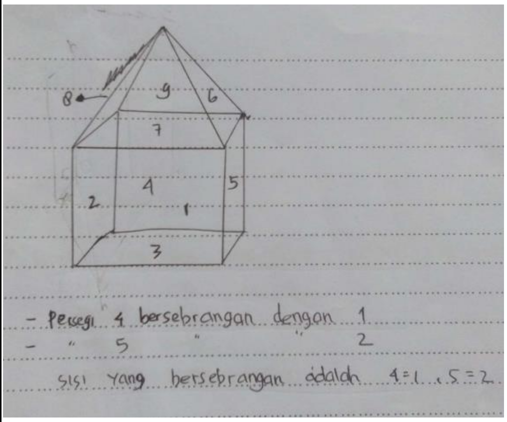
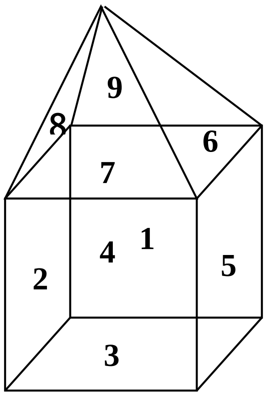
	Solution:  - Square 4 is opposite 1 - Square 5 is opposite 2 Opposite sides are 4 = 1, 5 = 2

Figure 7. FU’s answer with spatial visualization indicator

The results of the FU subject interview excerpts in understanding problem spatial visualization indicator are as follows.

Transcript 5. FU's interview excerpts in understanding problem spatial visualization indicator

P	:	Do you know what kind of space will be formed from the existing nets?	
S	:	Cube, ma'am?	
P	:	How many shapes will be formed?	
S	:	maybe 1 ma'am	
P	:	Are you sure?	
S	:	Yes, I'm sure ma'am	
P	:	As you can see on side number 7 is the front of the pyramid, how do you build that space?	
S	:	Ooo. This means that there are 2 geometric shapes, ma'am, a cube and a pyramid to form the geometric shape (*think for a moment*). We first raise sides number 7 and number 4, because side number 7 is the front side of the pyramid. Then the others followed, such as numbers 1 and 3, numbers 2 and 8, numbers 5 and 6.	V2
P	:	Which side number is the base of the cube?	
S	:	Number 3 ma’am	V1
P	:	Is it only number 3 that can be the base of a cube?	
S	:	Yes ma’am	
P	:	What is your reason?	
S	:	Because if the other side is the base, the cube will still be formed but side number 7 will no longer be in front.	V1
P	:	Yes, you're right. What do you think is the opposite side?	
S	:	Side number 4 with 4, side number 7 with 9, side number 2 with 5, and finally side number 8 with 6.	V1
P	:	Where is the base?	
S	:	The base is located below	V2
P	:	What about cover?	
S	:	The cover is on top	V2

P	:	Have you ever worked on problem like this?	
S	:	Never ma'am	
P	:	Are you having difficulty solving this problem?	
S	:	Yes, I'm having trouble	
P	:	What steps should you take to solve a problem like this?	
S	:	By reading the questions and looking at the pictures over and over again, after understanding I tried to make a net of the pictures onto another piece of paper. Then I cut it and assembled it until it became a cube and a pyramid	

Based on the results of work and interviews with the FU subject on problem spatial visualization indicator, information was obtained that the subject had good abilities in solving problems related to objects whose position and shape were manipulated. This was shown when the subject explained the side that was the base of the cube net, namely side number 3, and the subject also explains where the base and cover of the cube are located correctly. Subjects are also good at visualizing or seeing the composition of an object after its position and shape have been manipulated. This is shown when the subject explains the sides that need to be folded first, namely side number 7 on the grounds that this side is known as the front of the pyramid. The two sides number 4 are the front side of the cube, the three sides number 1 and 9 are the back side of the cube and the back of the pyramid, the four sides number 2 and 8 are the right side of the cube and pyramid and finally the sides number 5 and 6 are the left side of the cube and pyramid. The subject also explains the sides that are opposite each other, namely sides 4 → 1, 2 → 5, 7 → 9, and 8 → 6. The subject uses another piece of paper to make it easier to answer this problem.

Findings from Subject FU for Problem Spatial Mental Rotation Indicator

The following are the results of students' work on problem number spatial mental rotation indicator on the mental rotation indicator. The results of the interview excerpts from FU subjects in understanding the questions are as follows.

Transcript 6. FU's interview excerpts in understanding problem spatial mental rotation indicator

P	:	Do you know what kind of space will be formed from the existing nets?	
S	:	Cube, ma'am?	
P	:	How many shapes will be formed?	
S	:	maybe 1 ma'am	
P	:	Are you sure?	
S	:	Yes, I'm sure ma'am	
P	:	As you can see on side number 7 is the front of the pyramid, how do you build that space?	
S	:	Ooo, this means that there are 2 geometric shapes, ma'am, a cube and a pyramid to form the geometric shape (*think for a moment*). We first raise sides number 7 and number 4, because side number 7 is the front side of the pyramid. Then the others followed, such as numbers 1 and 3, numbers 2 and 8, numbers 5 and 6.	V2
P	:	Which side number is the base of the cube?	
S	:	Number 3 ma'am	V1
P	:	Is it only number 3 that can be the base of a cube?	
S	:	Yes ma'am	
P	:	What is your reason?	
S	:	Because if the other side is the base, the cube will still be formed but side number 7 will no longer be in front.	V1
P	:	Yes, you're right. What do you think is the opposite side?	
S	:	Side number 4 with 4, side number 7 with 9, side number 2 with 5, and finally side number 8 with 6.	V1
P	:	Where is the base?	

S : The base is located below V2
P : What about cover?
S : The cover is on top V2
P : Have you ever worked on problem like this?
S : Never ma’am
P : Are you having difficulty solving this problem?
S : Yes, I'm having trouble
P : What steps should you take to solve a problem like this?
S : By reading the questions and looking at the pictures over and over again, after understanding I tried to make a nets of the pictures onto another piece of paper. Then I cut it and assembled it until it became a cube and a pyramid

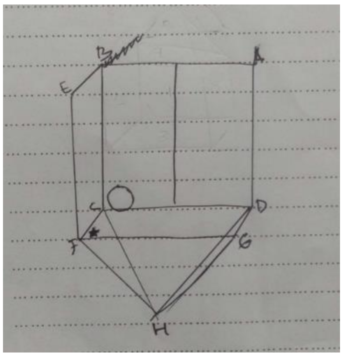


Figure 8. FU’s answer with spatial mental rotation indicator

Based on the results of work and interviews with the FU subject in problem spatial mental rotation indicator, information was obtained that the subject had a poor ability to rotate a spatial shape and imagine the rotation of the spatial shape correctly. This is shown when the subject knows the direction of rotation to the right (clockwise) but does not understand the amount of rotation (180˚) in the existing spatial shape. The subject also has good abilities in describing three-dimensional shapes after rotation. This is shown when the subject draws a shape that has been rotated, the subject mentions signs that have moved from their previous position, such as the star moving to the left, the circle moving to the left too, the pyramid moving down and the cube moving up.

Findings from Subject KS for Problem Spatial Perception Indicator

The following are the results of students' work on question number 1 on the spatial perception indicator.

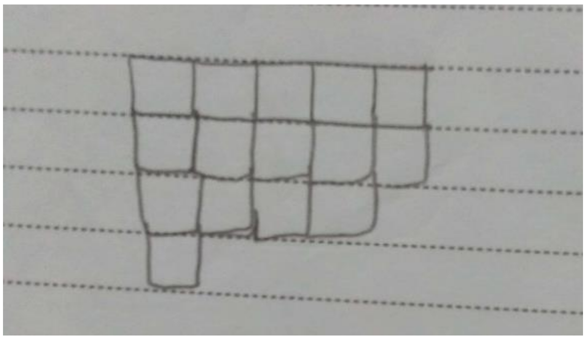


Figure 9. KS’s answer with spatial perception indicator

The following are the results of interview excerpts from subject KS's interview in understanding the following questions.

Transcript 7. KS's interview excerpts in understanding problem spatial perception indicator

P	:	Have you ever worked on questions like this?	
S	:	Not yet ma'am	
P	:	Do you think this question is difficult?	
S	:	It's difficult, ma'am	
P	:	Where is the difficulty in this problem?	
S	:	In the section to imagine the shape of a pile of cardboard seen from above	SP2
P	:	So, how do you solve this problem?	SP2
S	:	(*think for a moment*). First, I looked at the picture, then I tried to imagine the shape of the pile, but I had difficulty so I looked for a way to make it easier to answer this question. I'm trying to count the number of boxes. I cut the erasers that I no longer use, then I arranged the eraser pieces, exactly like the shape of the existing pile of cardboard. Like in the question, then I looked at it from above. So, I got a shape like this ma'am (while showing the picture)	
P	:	When you arrange the eraser pieces, do you think the pile looks the same, when viewed from the right and left?	
S	:	It's different ma'am	SP1
P	:	How many boxes are there in the pile?	
S	:	28 boxes ma'am	
P	:	In working on this problem, did you experience any difficulties?	
S	:	Yes ma'am. The first time I read the questions, I was already having difficulty	
P	:	How do you solve that difficulty?	
S	:	*(think for a moment*). I was trying to find a way to make it easier to answer the question, and I had an eraser that I didn't use. Then I cut the eraser, I arranged the eraser like the picture in the question, it turned out to be easier to answer.	SP2

Based on the results of work and interviews with KS subjects on problem spatial perception indicator, information was obtained that the subjects had good abilities in showing correct perception of the position and shape of geometric objects. This is shown when the subject correctly counts the number of boxes in the stack. The subject has good abilities in showing precise perception of the shape of a geometric object. This is shown when the subject correctly draws the shape of a stack of boxes seen from above and can differentiate the shape of a stack of boxes when seen from the right and left sides using the available media, namely an eraser cut into small blocks.

Findings from Subject KS for Problem Spatial Visualization Indicator

The following are the results of interview excerpts from subject KS's interview in understanding the following questions.

Transcript 8. KS's interview excerpts in understanding problem spatial visualization indicator

P	:	Have you ever worked on questions like this?	
S	:	Not yet ma'am	
P	:	Do you think this question is difficult?	
S	:	I think this problem is very difficult. So, I can't answer that, ma'am	
P	:	Do you know what spatial structure will be formed from the existing nets?	
S	:	I don’t know ma’am	
P	:	How many shapes will be formed?	
S	:	I don't know either ma'am	
P	:	Have you ever studied space geometry?	
S	:	I think so, but I forgot	
P	:	As you can see in question number 7, side is the front of the pyramid, how do you build the space?	
S	:	I don’t know	V2
P	:	Which side number is the base of the cube?	

S : I don't know either ma'am V1
P : What do you think is the opposite side?
S : I don’t know ma’am V1
P : Where is the base?
S : The base is located below V2
P : What about cover?
S : The cover is located at the top V2
P : What steps should you take to solve a problem like this?
S : I don't know, I still don't understand this problem

Based on interviews with subject KS on problem spatial visualization indicator, information was obtained that the subject had poor abilities in solving problems related to objects whose position and shape had been manipulated. This is shown when the subject cannot explain the side that is the base of the cube net. The subject is able to explain where the base and cover of the cube are located correctly. Subjects also have poor ability to visualize or see the composition of an object after its position and shape have been manipulated. This is shown when the subject cannot explain which sides are folded first and which sides are opposite.

Findings from Subject KS for Problem Spatial Mental Rotation Indicator

The following are the results of students' work on question number 3 on the mental rotation indicator.

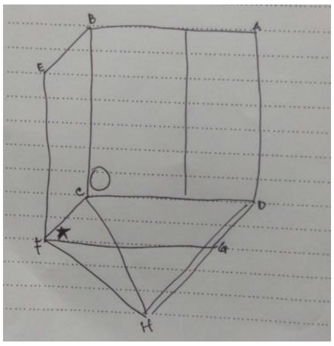


Figure 10. KS’s answer with spatial mental rotation indicator

The following are the results of interview excerpts from subject KS's interview in understanding the following questions.

Transcript 9. KS's interview excerpts in understanding problem spatial mental rotation indicator

P : So, if you look at a problem like this, what do you understand?
S : I see this image looks like box
P : Have you ever heard the words clockwise? What do you know?
S : (*think for a moment*). Clockwise means the clockwise direction is turning to the right
P : If it says counterclockwise?
S : The opposite, ma'am, means to the left
P : In the problem, the image is rotated 180˚ to the right. So, what do you think the signs will change?
S : If it is rotated 180˚, it means it is rotated in a half circle, so the image changes to the block at the top, the pyramid at the bottom and the signs that move to the round mark, to the bottom left, and the star sign to the bottom
P : In working on this problem, did you experience any difficulties?
S : No ma’am

Based on the results of work and interviews with subject KS on problem spatial mental rotation indicator, information was obtained that the subject had good abilities in rotating a spatial shape and imagining the rotation of a spatial shape correctly. This is shown when the subject knows the direction of rotation clockwise (to the right) and the rotation size (180˚) is half a rotation. The subject also has good abilities in describing three-dimensional shapes after rotation. This is shown when the subject draws a geometric shape that has been rotated in the right direction (clockwise) and the angle is large (180˚) and the subject also mentions signs that have moved from the previous position, such as the block at the top, the pyramid at the bottom, the sign that moves the round sign to the bottom left, and the star sign to the bottom.

Based on the description of the spatial perception indicators, students with high abilities show correct perception. This can be seen in the students' ability to show the position of geometric objects and students are able to describe the shape of a stack of boxes from above correctly, and based on the results of the interview, students were able to calculate the number of boxes in the pile correctly. This is in accordance with research results from Suparmi et al. (2022) and Putri (2020), stating that students who have high abilities have good spatial perception abilities and are able to solve problems correctly. For students in the medium category on the spatial perception indicator, students are able to count the number of boxes in a stack correctly and are able to describe the shape of the stack of boxes as seen from the top correctly. Furthermore, students in the low category have good spatial perception skills, where students are able to count the number of boxes and can describe stacks of boxes visible from the top. This is in accordance with research results from Prastyo (2017) and Fatmahanik (2021), which states that students in the high, medium and low categories have good spatial perception abilities.

In the visualization indicator, students with high and medium abilities have good visualization skills, this can be seen in students being able to explain the location of the sides of the net in the problem of being a cube and a pyramid and explaining the opposite sides completely and correctly. However, in the low category students the subject was not able to explain the location of the sides of the net in the problem of being a cube and a pyramid and explain the opposite sides completely and correctly. If we compare students in the high and medium categories, they have good spatial abilities, while students in the low category have low spatial abilities. Regarding visual spatial indicators, researchers found the same results as previous researchers, students with low abilities experienced difficulty in answering questions related to visual spatial (Azizah, 2022). Likewise with mental spatial rotation, based on research results, students with low abilities are unable to understand spatial orientation and have difficulty in solving geometry problems (Azizah, 2022). However, on the mental rotation indicator, researchers found a contradiction with the results of previous research. Students with low, medium and high abilities are able to answer questions related to mental rotation.

According to opinion Nuriswaty et al. (2020) and Kösa (2016), students in the high category had good visualization skills when compared to students in the low category. On the other hand Astuti et al. (2020), Nuriswaty et al. (2020) and Madya et al. (2023) stated that which revealed that visual skills and applied skills of students with high visual-spatial intelligence was better than students with low visual-spatial intelligence. The results of research by Aziz et al. (2017) also stated that students with high spatial intelligence gained better learning achievement and mathematical communication than students who had low spatial intelligence. To overcome students with low geometric abilities to have better spatial skills by providing a learning approach that can train students' spatial abilities. Based on research results by Sudirman and Alghadari (2020) that origami can be used as a valid and effective spatial training strategy. Origami allows students to understand spatial concepts in an interactive and visual way. Besides that, the approach that can be used to help train students' spatial abilities is the scientific approach, in accordance with research results from Anjarsari (2019) stating that the scientific approach allows students to understand spatial concepts in a more interactive way. Therefore, by using origami and scientific approach, students can develop spatial abilities such as spatial perception, spatial visualization and mental rotation.

Furthermore, on the mental rotation indicator, both high, medium and low students have the same abilities and can answer questions well. This is in line with research that after learning in spatial ability analysis, students with high, medium and low abilities were able to answer mental rotation questions, and based on the results of interviews with students, students were able to correct mistakes made in answering the questions related to mental rotation abilities (Akbar, 2021). Some limitations that may occur when analyzing spatial ability profiles in students' geometry learning include: (1) research conducted with small or unrepresentative samples of the student population may limit the generalizability of findings. Additionally, the composition of the sample not being demographically or academically diverse could also have influenced the results, (2) Limitations in research duration can limit understanding of the development of students' spatial abilities over time. Short studies may not be able to capture long-term changes or the effects of sustained learning interventions, (3) limitations in the objectivity of observers or assessors in interpreting spatial ability measurement results can influence the final interpretation of students' spatial ability profiles.

Conclusion

Based on the research results above, it can be concluded that the spatial ability profile of students in the high and medium categories in solving geometry problems is that they have good abilities in showing correct perception of the position of geometric objects; have good ability to show correct perception of the shape of a geometric object; however, low category students have good abilities in spatial perception but have poor abilities in visualization abilities. Students with high, medium and low abilities in solving geometry problems have good abilities in demonstrating mental rotation abilities. The recommendation suggested by researchers from this study is that geometry learning should use teaching media that is able to support spatial ability indicators so that students have much better spatial abilities. Furthermore, there should be further research on the spatial abilities of elementary and junior high school students.

References

Adolphus, T. (2011). Problems of teaching and learning of geometry in secondary schools in Rivers State, Nigeria. *International Journal of Emerging Sciences*, *1*(2), 143–152. Retrieved June 23, 2024, from https://dspace.stir.ac.uk/bitstream/1893/26189/1/Problems_of_Teaching_and_Learning_of_Geo.pdf

Akayuure, P., Asiedu-Addo, S. K., & Alebna, V. (2016). Investigating the effect of origami instruction on preservice teachers' spatial ability and geometric knowledge for teaching. *International Journal of Education in Mathematics, Science and Technology*, *4*(3), 198–209. https://doi.org/doi/10.18404/ijemst.78424

Akbar, K. (2021). Eksplorasi penelaran spasial pada konstruk rotasi mental dengan media Google SketchUp. *Jurnal Didaktika Pendidikan Dasar*, *5*(1), 143–164. https://doi.org/10.26811/didaktika.v5i1.203

Akıncı, M., & Genç, M. (2020). Pre-service teachers' explanations of primitive terms: point, line and plane. *Ilkogretim Online*, *19*(4). https://doi.org/https://doi.org/10.17051/ilkonline.2020.762588

Anjarsari, E. (2019). Mengembangkan kemampuan spasial siswa melalui pendekatan saintifik dalam pembelajaran matematika. *Jurnal Reforma*, *7*(2), 55. https://doi.org/10.30736/rfma.v7i2.77

Astuti, D. P., Sutopo, S., & Nurhasanah, F. (2020). An analysis of students geometry skills with different visual-spatial and logic-mathematic intelligence in solving the problem of solid plane geometry. *Journal of Mathematics and Mathematics Education*, *10*(1), 19. https://doi.org/10.20961/jmme.v10i1.37732

Aulia, I., Prayitno, S., Lu'luilmaknun, U., & Sridana, N. (2023). Analysis of students' spatial ability in solving problems of flat side space subjects based on Van Hiele's level of thinking. *Pijar MIPA*, *18*(1), 36–41. https://doi.org/10.29303/jpm.v18i1.3186

Aziz, A., Budiyono, B., & Subanti, S. (2017). The Effect of Inquiry Learning and Discovery Learning on Student Learning Achievement viewed from Spatial Intelligence. *Southeast Asian Mathematics Education Journal*, *7*(2), 59–70. https://doi.org/10.46517/seamej.v7i2.54

Azizah, I. N. (2022). *Analisis kemampuan spasial peserta didik dalam menyelesaikan soal matematika dengan pendekatan STEM (Science, Technology, Engineering, And Mathematics) Materi Dimensi Tiga Kelas XII IPA 2 SMAN Pakusari Kabupaten Jember*.[Unpublished thesis]. Universitas Islam Kiai Haji Achmad Siddiq Jember.

Azustiani, H. (2017). Kemampuan spasial siswa SMP Kelas VII ditinjau dari kemamuan matematika siswa di SMPN 1 Semen. *Prosiding SI MaNIs (Seminar Nasional Integrasi Matematika Dan Nilai Islami)*, *01*(1), 293–298. Retrieved June 21, 2024, from http://conferences.uin-malang.ac.id/index.php/SIMANIS

Bergstrom, C., & Zhang, D. (2016). Geometry interventions for K-12 students with and without disabilities: A research synthesis. *International Journal of Educational Research*, *80*, 134–154. https://doi.org/10.1016/j.ijer.2016.04.004

Cesaria, A., & Herman, T. (2019). Learning obstacle in geometry. *Journal of Engineering Science and Technology*, *14*(3), 1271–1280. Retrieved June 23, 2024, from https://jestec.taylors.edu.my/Vol 14 issue 3 June 2019/14_3_12.pdf

Dilling, F., & Vogler, A. (2021). Fostering spatial ability through computer-aided design: A case study. *Digital Experiences in Mathematics Education*, *7*(2), 323–336. https://doi.org/10.1007/s40751-021-00084-w

Fatmahanik, U. (2021). Penalaran spasial geometri ruang mahasiswa calon guru MI/SD berkemampuan awal tinggi berdasarkan gender. *Briliant: Jurnal Riset Dan Konseptual*, *6*(3), 513. https://doi.org/10.28926/briliant.v6i3.651

Gregory, R. J. (2011). *Psychological testing: History, principles, and applications 7th edition*. Pearson Education India.

Hibatullah, I. N., Susanto, S., & Monalisa, L. A. (2020). Profil kemampuan spasial siswa ditinjau dari tipe kepribadian florence littauer. *FIBONACCI: Jurnal Pendidikan Matematika Dan Matematika*, *6*(2), 115. https://doi.org/10.24853/fbc.6.2.115-124

Jones, K. (2003). Issues in the teaching and learning of geometry. In Haggarty, L. (Eds.). *Aspects of teaching secondary mathematics* (pp. 137–155). Routledge.

Karakırık, E. (2011). *Dinamik geometri ve Sketchpad ile geometri öğretimi. Matematik eğitiminde teknoloji kullanımı içinde*. Ankara. Nobel Yayın Dağıtım.

Kaufmann, H. (2011). Virtual environments for mathematics and geometry education. *Themes in Science and Technology Education*, *2*, 131–152. Retrieved June 22, 2024, from http://earthlab.uoi.gr/ojs/theste/index.php/theste/article/viewFile/60/42

Kösa, T. (2016). Effects of using dynamic mathematics software on pre-service mathematics teachers spatial visualization skills: The case of spatial analytic geometry. *Educational Research and Reviews*, *11*(7), 449–458. https://doi.org/10.5897/err2016.2686

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, *56*(6), 1479–1498. https://doi.org/10.2307/1130467

Lohman, D. F. (1993). *Spatial ability and G* [Seminar Session]. The First Spearman Seminar, University of Plymouth.

Madya, S., Rahman, A., & Ruslan. (2023). Analysis of ability to solve geometry problems in terms of spatial ability of class XII students of SMA Cokroaminoto Tamalanrea Makassar. *EduLine: Journal of Education and Learning Innovation*, *3*(2), 243–253. https://doi.org/10.35877/454RI.eduline1807

Maier, P. H. (1996). Spatial geometry and spatial ability–How to make solid geometry solid. In *Selected Papers from the Annual Conference of Didactics of Mathematics* (pp.63–75). Osnabrueck, Germany: Gesellschaft für Didaktik der Mathematik (GDM).

Maulana, H., Muzdalipah, I., Setialesmana, D., Musannadah, R., & Wali, L. S. (2023). Students error description and contributing factor in solving TIMSS geometry content domain problems based on their learning style. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *7*(2), 1558–1570. https://doi.org/10.31004/cendekia.v7i2.2326

McGee, M. G. (1979). Human spatial abilities: psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*, *86*(5), 889. https://doi.org/10.1037/0033-2909.86.5.889

Merriam, S. B. (2002). Introduction to qualitative research.pdf. In Merriam S. B. & Grenier, R. S. (Eds.), *Qualitative research in practice: examples for discussion and analysis* (pp. 3–17). John Wiley & Sons Inc.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis. A methods sourcebook* (3rd ed.). SAGE Publications Inc.

Mix, K. S., Levine, S. C., Cheng, Y.-L., Stockton, J. D., & Bower, C. (2021). Effects of spatial training on mathematics in first and sixth grade children. *Journal of Educational Psychology*, *113*(2), 304. https://doi.org/10.1037/edu0000494

NCTM. (2000). *Principles and standards for school mathematics.* National Council of Teachers of Mathematics, Inc.

Ningsih, I., & Haerudin. (2019). kemampuan spasial matematis siswa SMP kelas VIII pada materi bangun ruang sisi datar. *Prosiding Seminar Nasional Matematika dan Pendidikan Matematika Sesiomadika*, pp. 623–631. Universitas Singaperbangsa Karawang.

Ningsih, I. P., Budiarto, M. T., & Khabibah, S. (2021). Literasi spasial siswa SMP dalam menyelesaikan soal geometri ditinjau dari perbedaan gaya belajar. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(3), 1531–1540. https://doi.org/10.24127/ajpm.v10i3.3650

Nuriswaty, K. S., Pagiling, S. L., & Nurhayati, N. (2020). Visuospatial reasoning of eighth-grade students in solving geometry problems: A gender perspective. *Beta: Jurnal Tadris Matematika*, *13*(2), 152–167. https://doi.org/10.20414/betajtm.v13i2.400

Nurjanah, N., & Juliana, A. (2020). Hambatan didaktis siswa SMP dalam penyelesaian masalah geometri berdasarkan kemampuan persepsi ruang. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *11*(2), 236–244. https://doi.org/10.15294/kreano.v11i2.26752

Panaoura, G., Gagatsis, A., & Lemonides, C. (2007). Spatial abilities in relation to performance in geometry tasks. *These Proceedings*, *5*(1998), 1062. Retrieved June 23, 2024, from http://www.eled.uowm.gr/mathslife/arxeia selidas/PDF/47.pdf

Prastyo, Y. (2017). Deskripsi kemampuan spasial siswa smp ditinjau berdasarkan perbedaan gender dan kemampuan matematika. *Jurnal Ilmiah Soulmath: Jurnal Edukasi Pendidikan Matematika*, *5*(1), 22–30. https://doi.org/10.25139/sm.v5i1.454

Pujawan, I. G. N., Suryawan, I. P. P., & Prabawati, D. A. A. (2020). The effect of Van Hiele learning model on students' spatial abilities. *International Journal of Instruction*, *13*(3), 461–474. https://doi.org/10.29333/iji.2020.13332a

Putri, R. O. E. (2020). A study on the junior high school students' spatial ability and mathematics problem solving in mojokerto. *PEOPLE: International Journal of Social Sciences*, *6*(1), 775–783. https://doi.org/10.20319/pijss.2020.61.775783

Riastuti, N., Mardiyana, M., & Pramudya, I. (2017). Students' errors in geometry viewed from spatial intelligence. *Journal of Physics: Conference Series*, *895*(012029), 1-6. https://doi.org/10.1088/1742-6596/895/1/012029

Rittle-Johnson, B., Zippert, E. L., & Boice, K. L. (2018). The roles of patterning and spatial skills in early mathematics development. *Early Childhood Research Quarterly*, *46*, 166–178. https://doi.org/10.1016/j.ecresq.2018.03.006

Rohmah, M., Budiyono, & Indriati, D. (2021). Hass's theory: How is the students' spatial intelligence in solving problems? *Proceedings of the International Conference of Mathematics and Mathematics Education (I-CMME 2021)*, *597*, pp. 169–175. https://doi.org/10.2991/assehr.k.211122.024

Septia, T., Edriati, S., & Pratiwi, M. (2017). The effectiveness of interactive module based on Lectora™ to improve secondary school students' spatial ability. *Southeast Asian Mathematics Education Journal*, *7*(2), 95–102. https://doi.org/10.46517/seamej.v7i2.57

Soedjadi, R. (1991). Wajah pendidikan matematika di sekolah dasar kita. *Beberapa Hasil Pengamatan Lapangan Sebagai Upaya Perbaikan Di Masa Depan). Makalah Penataran Penyiapan Calon Penatar Dosen PGSD-DII Guru Kelas.* Jakarta.

Sudirman, S., & Alghadari, F. (2020). Bagaimana mengembangkan kemampuan spasial dalam pembelajaran matematika di sekolah?: Suatu tinjauan literatur. *Journal of Instructional Mathematics*, *1*(2), 60–72. https://doi.org/10.37640/jim.v1i2.370

Suparmi, S., Budayasa, I. K., & Setianingsih, R. (2022). Kemampuan spasial siswa SMP laki-laki maskulin dan perempuan feminin dalam memecahkan masalah geometri. *JRPM (Jurnal Review Pembelajaran Matematika)*, *7*(1), 35–54. https://doi.org/10.15642/jrpm.2022.7.1.35-54

Suwito, A. (2018). Analisis berpikir secara geometri dalam menyelesaikan masalah aljabar pada kelas VIII. *Prosiding Seminar Nasional Pendidikan Matematika Etnomatnesia*. Retrieved June 22, 2024, from https://jurnal.ustjogja.ac.id/index.php/etnomatnesia/article/view/2294

Syahputra, E. (2013). Peningkatan kemampuan spasial siswa melalui penerapan pembelajaran matematika realistik. *Cakrawala Pendidikan*, *3*(3), 353–364. https://doi.org/10.21831/cp.v3i3.1624.

Tessema, G. (2018). The relationship among spatial ability, van hiele level, and students' academic performance in geometry: The case of upper primary school students in fitche town, ethiopia. *International Journal of Innovative Research and Development*, *7*(12), 52–57. https://doi.org/10.24940/ijird/2018/v7/i12/DEC18005

Trimurtini, T., Student, D., & Semarang, N. (2021). Measuring spatial ability and geometric thinking level of prospective elementary school teachers using the rasch model. *İlköğretim Online*, *20*(1), 948–957. https://doi.org/10.17051/ilkonline.2021.01.91

Yenilmez, K., & Ozlem, K. (2015). Investigation of the relationship between the spatial visualization success and visual/spatial intelligence capabilities of sixth grade students. *International Journal of Instruction*, *8*(1), 189–204. Retrieved June 23, 2024, from https://eric.ed.gov/?id=EJ1085286