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Influence of Spatial Ability on Students' Mathematical Representation Ability in the Spatial Geometry Course

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ABSTRACT

This research aims to 1) Determine the spatial mathematical abilities of students in the spatial geometry course, 2) Understand the mathematical representation ability of students in the spatial geometry course, and 3) determine the influence of spatial ability on students' mathematical representation ability in the spatial geometry course. The research method uses a quantitative method with *a one-shot case study research design*. The research population is all students of the Department of Mathematics Education of UIN Siber Syekh Nurjati Cirebon who take the spatial geometry course in the odd semester of the 2024/2025 Academic Year, which consists of 3 classes: A, B, and C. The research sample was selected from 30 students from the research population using *a simple random sampling* technique. The data collection technique uses tests to determine students' spatial mathematical ability and mathematical representation ability. The results of the study showed that: 1) the student's mathematical spatial ability in the spatial geometry course averaged 77.23, included in the strong category; 2) students' mathematical representation ability in the spatial geometry course averaged 82.77, included in the strong category; and 3) mathematical spatial ability has a significant effect on students' mathematical representation ability in the spatial geometry course. Mathematical spatial ability has a 67% influences on students' mathematical representation ability in spatial geometry courses.

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1. INTRODUCTION

Geometry derives from the Greek words *geo*, which means earth, and *metro*, which means to measure. Geometry is a field of mathematics that Thales initially presented between 624 and 547 BC. Geometry studies the connections between geometric objects, such as points, lines, structures, and angles. Spatial geometry is one of the courses that students majoring in mathematics education must study. In the geometry course, students will learn about the concepts and calculations in building space [1], [2]. Studying spatial geometry courses requires many skills to optimise learning outcomes. The ability required to study spatial geometry courses is to understand and calculate mathematics, visualize, see, paint and imagine a geometric image, and re-display the image in visual, symbolic, and verbal forms [3], [4], [5], [6], [7]. The ability to visualize images, rotate images and observe objects that build space is related to mathematical spatial ability [8], [9], [10]. Meanwhile, the ability to re-display a geometric concept in various forms visually, symbolically and verbally is the ability of mathematical representation [11], [12].

According to Amstrong [13], spatial ability is the ability to see the spatial visual world accurately and make changes with vision or imagination. This ability relates to colour, line, build, shape, space, and relationships. Meanwhile, according to Linn & Petersen [14], spatial ability is a mental process of perceiving, storing, remembering, creating, changing, and communicating spatial structures. Meanwhile, Maier [15] stated that the indicator of spatial ability consists of five elements, namely: 1) *Spatial Perception*, which is the ability to require the location of the object that is being observed horizontally or vertically, 2) *Visualization,* which is the ability to show the rules of change or movement of the constituents of a building, either three-dimensional to two-dimensional or vice versa, 3) *Mental Rotation* is the ability to rotate two-dimensional and three-dimensional objects precisely and accurately, 4) *Spatial Relation* is the ability to understand the arrangement of an object and its parts and their relationship to each other, and 5) *Spatial Orientation* is the ability to observe an object from various circumstances.

Mathematical spatial ability is the ability to imagine, compare, guess, determine, construct, construct, construct, and find information from visual stimuli in the context of a room. This ability helps students to be able to express the position between the elements of a spatial building, identify and clarify geometric drawings, imagine the shape or position of a geometric object viewed from a certain point of view, construct and represent geometric models drawn on a flat plane in the context of space, and investigate a geometric object [16]. Indicators of mathematical spatial ability, namely: 1) *Spatial Perception*, 2) *Visualization*, 3) *Mental Rotation*, 4) *Spatial Relation*, and 5) *Spatial Orientation*.

NCTM [17] defines mathematical representation as the representation that is important to the study of mathematics. Students may grow and rely on their grasp of mathematical concepts and connections as they construct, compare, and employ diverse representations. Representation also helps pupils explain their ideas. "This remark might mean that representation is at the heart of mathematical learning. Students can expand and deepen their grasp of the concepts and links between mathematical concepts that they currently have by creating, comparing, utilizing, and aiding students in communicating. According to Lestari and Yudhanegara [16], mathematical representation is the ability to represent notations, symbols, tables, images, graphs, diagrams, equations, or other mathematical expressions in other forms.

According to NCTM [17], 1) Visual representation includes images, diagrams, graphs, and illustrations illustrating mathematical object relationships. This form is very useful in simplifying abstract concepts into more concrete and easy-to-understand forms.

For example, in geometry, triangle drawings or diagrams help students understand the properties of triangles. 2) Symbolic representation, a universal language in mathematics used to write theories, prove theorems, and solve problems. Although formal, symbolic representation using numbers, letters, and other notations makes communication more precise and concise, enabling students to express ideas in a structured way. 3) Verbal representation involves describing a mathematical concept or relationship using words or sentences. This form is essential for developing students' communication skills to articulate their understanding and explain ideas effectively to peers or teachers. 4) Numerical representation involves numbers and data for describing mathematical situations or phenomena. This is especially important in measurements, statistics, and calculations, helping students analyze data and solve problems systematically and precisely. These forms of representation collectively enable students to bridge the gap between abstract mathematical ideas and practical applications.

Indicators of representation ability, according to Villegas in Mulyaningsih et al. [18], are categorized into three forms: 1) verbal representation, answering a question using written statements or explanations, 2) visual representation, such as creating graphs, diagrams, or drawings to solve problems, and 3) symbolic representation, solving problems with mathematical models or symbols. These indicators provide a framework for assessing and developing students' competency in representing mathematical ideas effectively.

The study explored the relationship between mathematical spatial ability and representation skills in the spatial geometry course, aiming to examine how spatial ability impacts students' representation abilities. This research is essential for understanding the interplay between cognitive skills and academic competencies, particularly in geometry. The objectives of this study are: 1) to assess the spatial mathematical ability of students in the spatial geometry course, 2) to evaluate their mathematical representation ability, and 3) to determine the extent to which spatial ability influences representation skills. These objectives are grounded in the premise that spatial reasoning is crucial for effective problem-solving and conceptual understanding in geometry. The hypothesis posits that mathematical spatial ability significantly influences students' capacity for mathematical representation in spatial geometry courses, highlighting the importance of enhancing spatial skills to improve performance in geometry-related subjects. This research underscores the value of integrating spatial skill development into mathematics curricula to foster deeper understanding and better academic outcomes.

2. METHOD

This study employs a quantitative approach with a regression correlation method [19] to investigate the impact of spatial ability on students' mathematical representation abilities in the spatial geometry course. The research design was a one-time case study. The design of the study is as follows [20]:

$$\mathbf{X} \rightarrow \mathbf{Y}$$

Description:

X : mathematical spatial ability
→ : influence
Y : mathematical representation ability

The research population is all students of the Department of Mathematics Education of UIN Siber Syekh Nurjati Cirebon who take the spatial geometry course in the odd semester of the 2024/2025 Academic Year, which consists of 3 classes: A, B, and C. 30 students selected the research sample from the research population with *a simple random sampling* technique.

The data collection method involved administering tests to evaluate students' spatial mathematical ability and mathematical representation ability. These tests were distributed to the research sample, consisting of two types: one designed to assess spatial mathematical ability in the spatial geometry course and another to measure students' mathematical representation ability within the same course. The structured testing approach ensured comprehensive coverage of key cognitive skills required in spatial geometry.

The test items for spatial mathematical ability were developed based on specific indicators, including 1) Spatial Perception, the ability to determine the orientation of objects observed either horizontally or vertically; 2) Visualization, the skill to demonstrate transformations or movements of shapes, whether from three-dimensional to two-dimensional forms or vice versa; 3) Mental Rotation, the capacity to accurately rotate two-dimensional and three-dimensional objects; 4) Spatial Relation, the ability to comprehend the arrangement and relationships between an object and its components; and 5) Spatial Orientation, the skill to view objects from various perspectives.

Similarly, the test items for mathematical representation ability were based on three key indicators: 1) Verbal Representation, which involves answering questions through written explanations or descriptions; 2) Visual Representation, which entails creating graphs, diagrams, or illustrations to solve problems; and 3) Symbolic Representation, which focuses on solving problems using mathematical models and symbols. These indicators were carefully selected to align with the study's objectives, providing insights into the participants' diverse representational skills.

Before use, the mathematical spatial ability test instrument and the mathematical representation ability test are tested first to determine their validity, reliability, differentiation, and difficulty.

Furthermore, the two tests were given to research samples to obtain data. The data obtained from the research results are processed through the following stages:

1. Conduct a normality test to determine whether the data comes from a customarily attributed population.
2. Testing the homogeneity of the data variance to determine whether the data is homogeneous.
3. Testing a simple linear regression equation to determine the influence of an independent variable (X) on a dependent variable (Y).
4. Testing linearity to determine whether the regression equation obtained is linear.
5. Test regression coefficients to prove research hypotheses and determine the relationship's direction between the independent variable and the bound variable, whether positive or negative.
6. Testing the determination coefficient or goodness of the model to determine the contribution of the independent variable to the bound variable.

3. RESULTS

After processing the data of the results of the mathematical spatial ability test and the mathematical representation ability test in the spatial geometry course, the following results were obtained:

3.1. Mathematical Spatial Skills in the Spatial Geometry Course

Data on students' mathematical spatial abilities in the spatial geometry course were obtained from giving tests to 30 students. From the results of the mathematical spatial ability test, statistical description data is obtained as follows [21]:

Table 1. Statistical Description of Students' Mathematical Spatial Ability

	Mathematical Spatial Ability
N	30
Min	55
Max	95
Sum	2317
Mean	77,23
Std. dev	11,21

3.2. Mathematical Representation Skills in the Spatial Geometry Course

Data on students' mathematical representation skills in the spatial geometry course were obtained from giving tests to 30 students. From the results of the mathematical representation ability test, statistical description data was obtained as follows:

Table 2. Statistical Description of Mathematical Representation Ability of Students

	Mathematical Representation Ability
N	30
Min	60
Max	98
Sum	2483
Mean	82,77
Std. dev	13,03

3.3. Effect of Spatial Ability on Mathematical Representation Ability

Before testing the research hypothesis, the prerequisite tests are first carried out, namely the normality and homogeneity tests. The normality test was conducted to determine whether the data came from a normally distributed population. The statistical test to be used is the Kolmogorov-Smirnov test by taking a significant level (α) of 0.05 with the following statistical hypotheses:

H_0 : Data comes from a normally distributed population
H_1 : Data comes from populations that are not normally distributed

The test criteria are: H_0 is accepted if the significant value ≥ 0.05, and H_0 is rejected if the significant value < 0.05.

Table 3. Normality Test

Group	Mathematical Spatial Ability	Mathematical Representation Ability
N	30	30
Kolmogorov-Smirnov Z	0,153	0,200
Shapiro-Wilk	0,065	0,082
Conclusion	Normal	Normal

From the table above, data on mathematical spatial ability and students' mathematical representation ability came from a normally distributed population at a significance level of $\alpha = 0.05$.

Furthermore, because the data came from a normally distributed population, a homogeneity test was conducted to determine whether the data was homogeneous. The statistical test that will be used is the Levene test, taking a significant level (α) of 0.05. with the following statistical hypothesis:

H_0 : Both data have homogeneous variance
H_1 : Both data have non-homogeneous variances

The test criteria are: H_0 is accepted if the significant value ≥ 0.05, and H_0 is rejected if the significant value < 0.05.

Table 4. Homogeneity Test

Levene Statistic	df1	df2	Sig.	Conclusion
2,79	2	58	0,127	homogeneous

Based on the table above, it can be seen that the results of the homogeneity test have a significance value of 0.127 > 0.05, and H0 is accepted. So, it can be concluded that the data on mathematical spatial ability and the data on the students' mathematical representation ability are homogeneous.

Next, a simple linear regression test was carried out. Based on the calculation results, the following data was obtained:

Table 5. Simple Linear Regression Test

Regression Equation		Unstandardized Coefficients		T	Sig.
		B	Std. Error		
1	Constant	2,64	11,42	0,29	0,17
	Spasial matematis	1,29	0,158	5,62	0,00

Based on the table above, the regression equation is obtained:
$Y = 2,64 + 1,29 X$.

The hypothesis test was carried out to determine whether mathematical spatial ability influenced students' mathematical representation ability in the spatial geometry course. Then, a hypothesis test was carried out with the following hypothesis provisions:

H_0 : Mathematical spatial ability does not have a significant effect on students' mathematical representation ability in spatial geometry courses

H_1 : Mathematical spatial ability has a significant effect on students' mathematical representation ability in the spatial geometry course

The test criteria are:
H_0 is accepted if the significant value ≥ 0.05
H_0 is rejected if the significant value < 0.05.

The calculation results obtained in Table 5 show that the significance value (Sig) is $0.00 < 0.05$, so the null hypothesis is rejected. Therefore, it can be concluded that mathematical spatial ability significantly affects students' mathematical representation ability in the spatial geometry course.

Next, a linearity test was carried out. This test determines whether the relationship between the two variables of linear research is good. The data obtained has a significant linear value of 0.00. Because the significance value is less than 0.05, the relationship is linear.

Based on the regression equation, the regression coefficient is 1.29. It states that every addition of mathematical spatial ability will affect the mathematical representation ability by 1.29. A positive coefficient means a positive relationship between mathematical spatial ability and mathematical representation ability; the higher the mathematical spatial ability, the better the mathematical representation ability will be.

The goodness of the model or the determination coefficient test is used to determine the percentage of the influence of mathematical spatial ability on students' mathematical representation ability in spatial geometry courses.

Table 6. Coefficient of Determination Test

Model	R	R square	Adjusted R square	Std. Error of the Estimate
1	0,82	0,67	0,85	0,71

From the table above, it can be seen that the value of the determination coefficient (R Square) is 0.67. This means that 67% of the variables of students' mathematical representation ability (Y) are influenced by variable X, namely students' mathematical spatial ability or, in other words, the influence of mathematical spatial ability on students' mathematical representation ability in the spatial geometry course is 67%.

4. DISCUSSION

The study results showed that the spatial mathematical ability of students in the spatial geometry course was included in the strong category, with an average score of 77.23. This is consistent with Amstrong's [13] research, which states that mathematical spatial ability is related to accurately observing the spatial visual world and making changes through vision or imagination. This ability is essential in studying spatial geometry, which requires visualization and manipulation of spatial objects.

Students' mathematical representation skills are also in the strong category, with an average score of 82.77. These results align with NCTM's [17] definition that mathematical representation is at the core of mathematical learning, helping students expand and deepen their understanding of mathematical concepts through various forms of representation. This study corroborates the findings of Mulyaningsih et al. [18] that the ability to represent verbally, visually, and symbolically is essential in solving mathematical problems.

In addition, the finding that mathematical spatial ability exerts a 67% influence on mathematical representation ability shows a significant relationship between the two variables. These findings support previous research by Tambunan [22], which found a positive association between spatial ability and math learning achievement, including representational ability. These results are also in line with the research of Siswanto [23], which shows that spatial geometry ability can improve mathematical creative thinking, one of the essential elements in mathematical representation.

Furthermore, the regression results show that every increase in mathematical spatial ability by one unit will increase the mathematical representation ability by 1.29 units. This positive relationship shows that the development of mathematical spatial ability can be one of the essential strategies to improve students' mathematical representation ability. In the context of learning, these results emphasize the importance of teaching methods supporting the visualization and manipulation of spatial objects, such as technology-based learning [24] or using software such as GeoGebra [25].

This finding provides practical implications for educators, especially in spatial geometry courses, to prioritize the development of students' spatial abilities. On the other hand, the limitations of this study, such as the small sample size and limited population coverage, open up opportunities for further research on a larger scale to reinforce the generalization of results.

5. CONCLUSION

Based on the results of the research and discussion on the influence of mathematical spatial ability on the mathematical representation ability of students in the spatial geometry course, it was concluded that 1) the average spatial mathematical ability of students in the spatial geometry course was 77.23, included in the strong category; 2) students' mathematical representation ability in the spatial geometry course averaged 82.77, included in the strong category; and 3) mathematical spatial ability has a significant effect on students' mathematical representation ability in the spatial geometry course. Mathematical spatial ability has a 67% influences on students' mathematical representation ability in the spatial geometry course.

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