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Spatial ability and learning achievement in transformation geometry: A correlation study

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Abstract

Spatial ability is one of the essential factors for individuals' success in learning geometry. However, limited studies have specifically explored the extent to which spatial ability affects students' achievement in transformation geometry. This study aims to investigate the correlation between spatial ability and the learning achievement of mathematics education students in transformation geometry courses. A quantitative approach with a causal-correlational design was employed. The population consisted of all fourth-semester students enrolled in the Mathematics Education Study Program at IAIN Pontianak, totaling 28 students. The entire population was selected as the sample using the total sampling technique. Data on spatial ability were collected through a spatial ability test, while data on learning achievement in transformation geometry were obtained through documentation. The collected data were analyzed using descriptive and inferential statistics, including correlation analysis, t-tests, and simple linear regression analysis. The findings reveal a positive and statistically significant relationship between spatial ability and learning achievement in transformation geometry. Consequently, lecturers must design strategies that effectively accommodate and enhance students' spatial abilities. Improving spatial ability is expected to contribute positively to students' learning achievement in transformation geometry courses.

Keywords: Spatial ability, Learning achievement, Transformation geometry

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INTRODUCTION

Geometry is one of the significant fields within mathematics. Through geometry, individuals can abstract visual and spatial experiences from their surroundings, as well as learn to measure, compare, and analyze various shapes and patterns. According to (Susanto et al., 2021), the uniqueness of studying geometry lies in the fact that students are not only required to master geometric concepts but also to develop several practical skills, such as visual, verbal, drawing, logical, and applied skills. Furthermore, the integration of spatial abilities into geometry learning frameworks has gained significant attention due to their critical role in solving geometric problems (Wardhani et al., 2023). Therefore, fostering both conceptual understanding and spatial skills is essential for optimizing geometry learning achievement.

Learning achievement is regarded as a significant indicator to reflect the success of students in mastering knowledge or a particular skill. A study conducted by (Saputro et al.,

2015) revealed that initial ability, motivation, study habits, learning environment, and learning facilities simultaneously have a significant impact on the learning achievement of mathematics education students. Meanwhile, in the context of geometry, two factors that influence geometry learning achievement are spatial ability (Hodiyanto, 2018) and the level of geometric thinking (Rizqiyani et al., 2017). Therefore, it can be concluded that geometry learning achievement is influenced by spatial ability, the level of geometric thinking, as well as other factors.

Spatial ability is considered highly important for understanding geometric concepts, including transformation geometry (Rustanuarsi, 2023). According to (Clements and Battista, 1992), spatial ability is defined as a set of cognitive processes that enable individuals to create and manipulate mental representations of spatial objects, the relationships between objects, and the transformations that occur. Additionally, (Idris, 2006) describes spatial ability as the capacity to comprehend the essential relationships among elements in a given visual situation, as well as the ability to mentally manipulate one or more of these elements. Spatial ability encompasses various aspects, including mental rotation, spatial orientation, and spatial visualization (Lowrie et al., 2016). Therefore, it can be concluded that spatial ability refers to an individual's capacity to understand objects in their environment, such as imagining how an object would appear if rotated or reflected.

Transformation geometry is one of the courses offered in the curriculum of the Mathematics Education Study Program at IAIN Pontianak. This concept has been introduced at the high school level in grade XI, but at the university level, the discussion is more in-depth and involves comprehensive analysis. Transformation geometry refers to operations applied to the geometric representation of an object to alter its position, orientation, or size (Hearn et al., 2014). In studying transformation geometry, good spatial ability is required, which is characterized by the ability of students to imagine how the position and orientation of objects change. With a deep understanding of transformation geometry, students are expected to achieve high academic performance and be able to apply these concepts in various contexts.

Based on a preliminary study conducted during the transformation geometry course in the Mathematics Education Study Program, it was found that some students still struggle to master the material on transformation geometry. This indication can be seen from the average student learning achievement which reached 70,21, which falls into the B category. Although this score reflects a satisfactory level of achievement, it also suggests that some students have not yet fully grasped the concepts of transformation geometry. Furthermore, it was observed that some students face difficulties in visualizing the orientation of objects when reflected or rotated, which is closely related to their spatial ability.

Several previous studies have examined the relationship between spatial ability and geometry learning. (Mahfuddin and Caswita, 2021) found that students with high spatial ability perform better in solving transformation geometry problems based on high-order thinking compared to students with moderate or low spatial ability. Furthermore, (Ihsan et al., 2024) demonstrated that spatial ability has a direct and significant positive influence on junior high school students' geometry learning outcomes. Additionally, (Pradana and Sholikhah, 2023) revealed that spatial reasoning plays a crucial role in constructing and processing solutions to geometry problems. These findings suggest that spatial ability is a key factor in understanding and mastering geometry.

However, a gap remains in the literature regarding the relationship between spatial ability and learning achievement in transformation geometry courses, particularly among mathematics education students. Therefore, this study aims to analyze the relationship between spatial ability and learning achievement in the transformation geometry course among students enrolled in the Mathematics Education Study Program at IAIN Pontianak.

RESEARCH METHODS

The aim of the research is to examine the relationship between spatial ability and students' learning achievement in the transformation geometry course. This study employs a quantitative research approach with a correlational design using the ex post facto method. The study was conducted in the odd semester of the 2022/2023 academic year in the Mathematics Education Study Program at IAIN Pontianak. The population of this study consists of all 28 fourth-semester students enrolled in the transformation geometry course. A total sampling technique was used in this study, meaning the entire population serves as the research sample.

The independent variable in this study is spatial ability, while the dependent variable is learning achievement in transformation geometry. The research data were collected through a spatial ability test and documentation of transformation geometry learning achievement. The spatial ability test was designed with three indicators: mental rotation, spatial orientation, and spatial visualization. Each indicator was measured using 10 items, resulting in a total of 30 items. Expert validation was conducted to ensure the content validity of the test items before being tested.

Subsequently, the obtained data were analyzed using descriptive and inferential statistics. Descriptive statistics were employed to describe the characteristics of the data, while inferential statistics were used to test the formulated hypotheses. The research hypothesis states that there is a positive and significant relationship between spatial ability (X) and learning achievement (Y). Hypothesis testing was conducted by applying *Pearson Product Moment* correlation analysis, t-test, and simple linear regression analysis. Before hypothesis testing, it is necessary to test the fulfillment of several assumptions including tests for normality, linearity, and heteroscedasticity.

RESULTS AND DISSCUSSION

The research data were collected from documents on transformational geometry learning achievements and the results of students' spatial ability tests. This section will present the findings of the data analysis, which includes both descriptive and inferential analyses. The descriptive analysis reveals that the average score of students' spatial ability is 13,46. Additionally, the average score for students' transformational geometry learning achievement is 70,21. Table 1 provides a detailed overview of the descriptive analysis results for spatial ability and learning achievement.

Table 1. Descriptive Statistics Summary

Statistics	**Spatial Ability (X)**	**Learning Achievement (Y)**
Theoretical Max	30	100
Theoretical Min	0	0
Maximum	24	96,67
Minimum	3	40,5
Mean	13,46	70,21
Std Deviation	5,78	15,17
Variance	33,51	230,29

The students' spatial ability achievements are presented in Table 2. The overall average achievement is 44,88%. In general, students demonstrate better mental rotation abilities compared to spatial orientation and spatial visualization abilities. Overall, there is still potential for improving students' spatial abilities.

Table 2. Percentage of Spatial Ability Achievement

Aspect	**Results**
Mental Rotation	53,57%
Spatial Orientation	40,71%
Spatial Visualization	40,36%
Average	44,88%

Before employing inferential statistics, it is necessary to verify the fulfillment of several assumptions, namely normality, linearity, and no heteroscedasticity. In this study, the assumption of data normality was tested using residual values through the *Kolmogorov-Smirnov* test. The results of this test yielded a significance value of 0,2, which is greater than the significance level α = 0,05. Therefore, it can be concluded that the data are derived from a normally distributed population. Thus, the assumption of normality is satisfied for this data. The complete results of the normality assumption test are presented in Table 3.

Table 3. Normality Test Results

		Unstandardized Residual
N		28
Normal Parameters	Mean	0
	Std. Deviation	7,711
Most Extreme Difference	Absolute	0,118
	Positive	0,118
	Negative Most	-0,066
Test Statistic		0,118
Asymptotic Significance (2-tailed)		0,200

The next test conducted is the linearity test. Based on Table 4, the significance value for deviation from linearity is 0,616, which is greater than the significance level α = 0,05. Therefore, it can be concluded that there is a significant linear relationship between spatial ability and learning achievement.

Table 4. Linearity Test Results

		F	**Sig.**
Learning Achievement (Y) Spatial Ability (X)	(Combined)	5,384	0,003
	Linearity	68,810	0,000
	Deviation from Linearity	0,854	0,616

The subsequent step involves evaluating the assumption of heteroscedasticity in the regression model by examining the scatterplot of residuals. The test results can be observed in Figure 1. Based on visual inspection, the distribution of data points appears random without forming any specific pattern. This indicates the absence of heteroscedasticity in the data. Consequently, the assumption of homoscedasticity in the regression model is satisfied, allowing the regression model to be used for statistical inference.

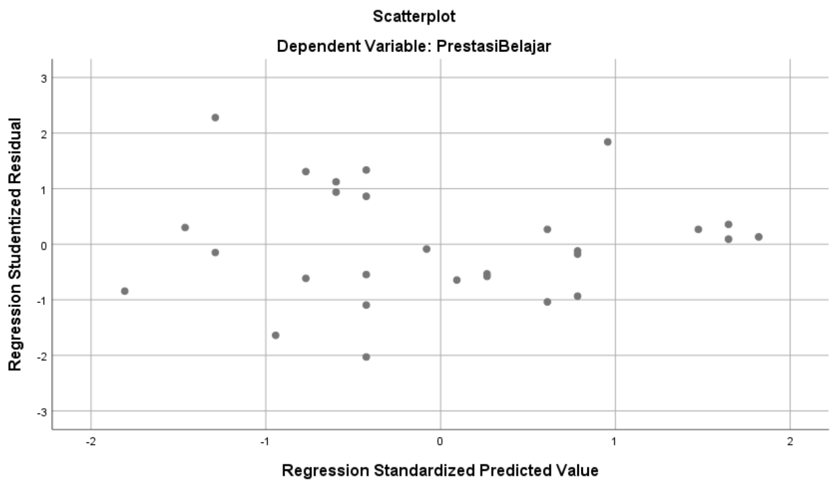

Figure 1. Results of the Heteroscedasticity Test Scatterplot.

The assumption tests conducted indicate that the data are normally distributed, there is a significant linear relationship between spatial ability and learning achievement, and there is an absence of heteroscedasticity. The fulfillment of these assumptions allows for the application of statistical inference.

The correlation between variables in this study was analyzed using the *Pearson Product Moment* correlation test. The results of the correlation analysis are presented in Table 5, and the correlation coefficient obtained is 0,861. This indicates a positive and very strong relationship between the variables of spatial ability and transformational geometry learning achievement (Siregar, 2017: 202). This means that students with higher spatial abilities tend to demonstrate better learning achievement in transformation geometry.

Table 5. Pearson Correlation Test Results

		Spatial Ability	**Learning Achievement**
SpatialAbility	Pearson Correlation	1	0,861
	Sig. (2-tailed)		0,000
	N	28	28
LearningAchievement	Pearson Correlation	0,861	1
	Sig. (2-tailed)	0,000	
	N	28	28

The next test conducted is the significance test of the correlation using the t-test, the formula for which is shown in equation (1).

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \qquad (1)$$

The testing criterion is that if $\mathrm{t_{calculated}} > \mathrm{t_{table}}$ then there is a significant relationship (Siregar, 2017: 206). Given that r = 0,861 and n = 28, the calculation of $\mathrm{t_{calculated}}$ is elaborated in equation (2).

$$\mathrm{t} = \frac{0{,}861\sqrt{28-2}}{\sqrt{1-(0{,}861)^2}} = 8{,}621 \qquad (2)$$

Based on the t-distribution table with a significance level of 5% and degrees of freedom $\mathrm{df} = 28 - 2 = 26$, the critical value $\mathrm{t_{table}}$ is obtained as 2,056. Since the calculated value if $\mathrm{t_{calculated}}$ (8,621) is greater than $\mathrm{t_{table}}$ (2,056), it can be concluded that there is a statistically significant relationship between spatial ability and transformation geometry learning achievement.

A simple linear regression analysis was conducted as a follow-up analysis. The results of the analysis, presented in Table 6, show the obtained regression equation as $\hat{Y} = 39{,}818 + 2{,}258X$. The regression coefficient of the independent variable (spatial ability) of 2,258 indicates that each unit increase in spatial ability is associated with an average increase of 2,258 units in learning achievement.

Tabel 6. Output SPSS Model Regresi (Coefficients[a])

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	39,818	3,818		10,430	0,000
SpatialAbility	2,258	0,261	0,861	8,643	0,000

a. Dependent Variable: Learning Achievement

The Coefficient of Determination is used to measure the magnitude of the contribution of spatial ability variables in explaining variations in geometry transformation learning achievement variables. Table 7 presents the results of simple linear regression analysis, where the R^2 value is 0,742, resulting in a coefficient of determination value of 74,2%. This value indicates that approximately 74.2% of the variation in learning achievement can be explained by the variation in spatial ability. Thus, the predictor variable (spatial ability) contributes to the learning achievement of transformation geometry.

Table 7. Ouput SPSS Model Regresi (Model Summary)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,861[a]	0,742	0,732	7,85800

a. Predictors: (Constant), Spatial Ability

Based on the data analysis conducted, a statistically significant relationship was found between spatial ability and learning achievement in transformation geometry among mathematics education students. This finding indicates that the higher a student's spatial ability, the higher the possibility of them achieving good performance in the course. The same applies conversely. The results of this study strengthen the findings of Hodiyanto (2018), which state that spatial ability plays a crucial role in determining success in learning geometry. Additionally, this finding supports the research results of Mahfuddin and Caswita (2021), which demonstrates that high spatial ability enhances the capacity to solve a higher-order thinking problem in transformation geometry.

In this study, the measurement of students' spatial ability includes three main aspects, namely mental rotation, spatial orientation, and spatial visualization. Mental rotation refers to the ability to accurately rotate simple geometric objects in one's mind without needing to imagine oneself in a specific orientation Lowrie et al. (2016). This ability aids students in understanding and solving transformation problems such as rotation and reflection. Spatial orientation refers to the ability to comprehend the relationship between the position of an object and one's own position. In other words, the object remains stationary, and the observer must shift their perspective. To understand transformation geometry, learners need to possess strong spatial orientation skills. This is because transformations often involve changes in the position of objects, requiring an understanding of how the object will appear from different viewpoints. Meanwhile, spatial visualization is the ability to imagine how an object or its parts rotate (Olkun, 2003). This skill helps learners visualize how objects change when transformation operations are applied.

There is a positive and significant relationship between spatial ability and learning achievement in transformation geometry, then lecturers are advised to integrate strategies that can enhance students' spatial ability into the learning process. Several research findings related to efforts to improve spatial ability include: 1) GeoGebra-based discovery learning models Fajri et al. (2017); 2) a scientific approach (Anjarsari, 2019). Sudirman and Alghadari (2020), in their literature review, mention several methods to enhance spatial ability, such as: 1) the use of spatial language in everyday conversations; 2) teaching sketching and drawing; 3) the utilization of relevant games; 4) the use of tangrams; 5) playing video games; and 6) engaging in origami and paper-folding activities.

CONCLUSION

Based on the results of the data analysis, there is a positive and significant relationship between spatial ability and learning achievement in transformation geometry among mathematics education students, with a correlation coefficient of 0,861, categorized as very strong. This finding indicates that students with high spatial ability tend to achieve high performance in transformation geometry, and vice versa. Therefore, the development of spatial ability should be a primary focus in efforts to enhance students' learning achievement in geometry, particularly transformation geometry.

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