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An Analysis of Differences in Spatial Ability Among Junior High School Students by Their Level of Self-Efficacy

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Abstract

This study aims to describe the differences in spatial ability based on self-efficacy levels among public junior high school students in the city of Yogyakarta. This research is a quantitative survey study with an ex post facto approach, conducted on 391 public junior high school students in the city of Yogyakarta. The research data were collected using a spatial ability test instrument and a self-efficacy questionnaire. The validity and reliability of the instruments were established, based on the Aiken's V rater agreement index and Confirmatory Factor Analysis for the self-efficacy questionnaire, as well as instrument reliability using Cronbach's Alpha. The analysis performed was inferential analysis at a 0.05 significance level, using Welch's ANOVA, the Games-Howell test, and Mean Value Estimation. The analysis results revealed a significant difference in the spatial ability of the student group with a "Very Low" self-efficacy level compared to all groups with "Low," "Medium," "High," and "Very High" self-efficacy levels. Meanwhile, the average spatial abilities among the "Low," "Medium," "High," and "Very High" self-efficacy levels were the same.

Keywords: *Spatial Ability; Self-Efficacy*

Introduction

To study mathematics is to also study a branch of mathematics, namely the science of geometry (Maarif, 2015). Learning geometry requires the ability to visualize, reason, and use geometric models to solve problems. The visualization in question is a person's perception of an object, which then influences their spatial ability, the capacity to imagine an object without seeing its physical form (Maarif, 2015). Nugroho, (2017) states that in studying solid geometry, students are required to possess spatial ability. This ability relates to colors, lines, figures, shapes, space, and their interrelationships. It includes the ability to imagine, describe spatial ideas, and accurately explain spatial arrangements. Muthumari & Shanti (2023) add that spatial visualization is the skill of forming mental images, imagining shapes, mentally rotating objects, and understanding the relationships between parts, such as when assembling puzzle pieces. Another definition is put forward by Baranová & Katreničová (2018), who define spatial ability in three types: recognizing objects from different viewpoints, visualizing the movement of parts within a configuration, and analyzing spatial relations by considering the observer's body orientation. Meanwhile, Gardner (1999) defines spatial ability as the potential to recognize and manipulate the patterns of both wide spaces, such as those used by navigators and pilots, and more confined areas, such as those used by sculptors, surgeons, graphic designers, artists, and architects.

Spatial tests also require the ability to manipulate, transpose, apply, and recognize geometric forms (Smith, 1964). This spatial ability is not only relevant in learning geometry but is also highly necessary in various academic selection tests that students will eventually face, both in and out of school, such as academic tests for job applications. Thus, honing spatial ability from the junior high school level needs to be a point of focus, so that students are better prepared to face academic challenges and other formal selections.

Besides the importance of equipping students with adequate spatial ability, the development of self-efficacy is also a matter that requires attention. The theory of self-efficacy, according to (Bandura, 1995), states that self-efficacy refers to an individual's belief in their own capability to organize and execute the courses of action required to manage prospective situations. This self-efficacy influences how people think, feel, motivate themselves, and act. This concept functions as a self-regulatory mechanism that influences a person's behavior, particularly in the academic domain (Zimmerman & Schunk, 2008), including in solving complex and challenging mathematics tasks (Lenz & Shortridge-Baggett, 2002).

Furthermore, Bandura also stated that those with high self-efficacy have the ability to strive for success, thus providing positive support for their performance. Conversely, individuals with low self-efficacy tend to doubt their abilities, visualize failure, and get trapped in negative thoughts that can hinder their achievements. Grotan et al. (2019) in their research also state that self-efficacy represents an individual's belief in their ability to manage stress and face various challenges. When students believe they can master spatial ability in geometry, it will encourage the emergence of positive attitudes such as seriousness in following lessons, the ability to complete tasks optimally, active participation during the learning process, the thorough and timely completion of assignments from the teacher, and a positive response to the various challenges presented.

Safadel et al. (2023) in their research found that there is a significant positive relationship between spatial self-efficacy and spatial ability. Bandura (1997) also stated there is a positive correlation between students with high self-efficacy and their cognitive achievements. Based on these points, it is evident that there is a link between spatial ability and student self-efficacy. Therefore, this research was conducted to obtain a more comprehensive understanding of the extent to which self-efficacy contributes to students' spatial ability. Consequently, the results of this study are expected to serve as a basis for developing learning strategies that can be used to support the geometry learning process in schools, making it more effective and capable of accommodating the different psychological characteristics of students.

Method

This study is a quantitative survey research using an ex post facto approach, conducted to determine if there is a significant difference in students' spatial ability when viewed from their level of self-efficacy. The research was implemented in three stages: (1) Administering the self-efficacy questionnaire; (2) Administering the spatial ability test questions; and (3) Analyzing the data and formulating conclusions. These three stages were carried out from February to March 2025, involving 391 public junior high school students in the city of Yogyakarta as the sample. The sample was selected using stratified random sampling (n=385) from an initial population of 10,399 public junior high school students throughout the city of Yogyakarta. This sample selection aimed to ensure representation from every category of public junior high school in the city of Yogyakarta.

The research data were collected using two main instruments: a spatial ability test and a self-efficacy questionnaire. The validation process was conducted by a team of expert validators with a deep understanding of field assessment techniques. Validity was established based on the calculation of the Aiken's V rater agreement index for both instruments (V>0.63). The construct validity of the self-efficacy questionnaire, involving 122 students, was analyzed using the Confirmatory Factor Analysis technique, which yielded V values > 0.43 for all questionnaire items. Furthermore, the instrument reliability was confirmed with Cronbach's Alpha (r > 0.72).

The analysis performed consisted of: (1) Univariate prerequisite tests: ensuring no univariate outliers, that the data were univariately normally distributed, and that the homogeneity of variance was met; (2) Quantitative descriptive analysis, which included categorizing self-efficacy into five levels: very low, low, medium, high, and very high, based on Table 1; (3) Inferential analysis at a 0.05 significance level using Welch's ANOVA to examine if there were differences in spatial ability based on self-efficacy levels, the Games-Howell test to identify where the differences in spatial ability occurred among the self-efficacy levels, and the Mean Value Estimation test to observe the average value of spatial ability based on each self-efficacy level.

Table 1. Self-Efficacy Level Category

Interval	Category
$X > M_i + 1{,}5S_i$	Very High
$M_i + 0{,}5S_i < X \leq M_i + 1{,}5S_i$	High
$M_i - 0{,}5S_i < X \leq M_i + 0{,}5S_i$	Medium
$M_i - 1{,}5S_i < X \leq M_i - 0{,}5S_i$	Low
$X \leq M_i - 1{,}5S_i$	Very Low

Results and Discussion

Results

Based on the collected research data, all data fulfilled the univariate assumptions, namely: there were no univariate outliers, and the data were univariately normally distributed. However, the spatial ability data were not homogeneous, as a p-value < 0.05 was found. Based on the results of the descriptive analysis, the distribution of self-efficacy level categories was obtained and divided into the five following categories.

Table 1. Distribution of Self-efficacy Categories

Self-Efficacy Level	Amount	Percentage
Very Low	6	1.53%
Low	10	2.57%
Medium	28	7.16%
High	222	56.78%
Very High	125	31.97%

Based on the data in Table 2, a Welch's ANOVA test was conducted to examine the differences in spatial ability based on self-efficacy levels, with the results presented in Table 3. This was followed by a Games-Howell test to identify where the differences in spatial ability occurred among the self-efficacy levels, with the results presented in Table 4.

Table 2. Results of Welch's ANOVA Test

F	Num df	Denom df	p-value
54.286	4.000	24.363	8.757e-12

Table 3. Results of Games Howell Test

	Group 1 (Self-Efficacy Level)	Group 2 (Self-Efficacy Level)	p.adj (p-value)
Spatial Ability	Very Low	Low	0.005
	Very Low	Medium	0.000000113
	Very Low	High	0.0000433
	Very Low	Very High	0.0000224
	Low	Medium	0.372
	Low	High	0.553
	Low	Very High	0.483
	Medium	High	0.755
	Medium	Very High	0.931
	High	Very High	0.957

Based on the analysis results in Table 3, it was found that there is a significant difference in students' spatial ability based on their self-efficacy category, as indicated by a p-value of less than 0.05. Table 4 shows that the significant difference in spatial ability is between the "Very Low" self-efficacy category and the "Low," "Medium," "High," and "Very High" self-efficacy levels, which yielded a p-value < 0.05.

In contrast, among the "Low," "Medium," "High," and "Very High" self-efficacy levels, there was no significant difference in spatial ability, as shown by a p-value > 0.05, with the average spatial ability for each self-efficacy level category being as follows.

Table 54. Average Spatial Ability at Each Level of Self-Efficacy

Self-Efficacy Level	Average Spatial Ability	Confident Interval (95%)	Category
Very Low	8.166667	-1.415242 – 17.748575	Very Low
Low	51.7	31.82216 – 71.57784	Medium
Medium	69.39286	63.23113 – 75.55458	High
High	65.51051	63.38586 – 67.63516	High
Very High	66.72	64.0425 – 69.3975	High

Table 5 shows the average spatial ability scores distributed across five different levels of self-efficacy. There is a clear and significant performance gap between the "Very Low" self-efficacy group (average score of 8.17) and all other groups. As self-efficacy increases from "Low" to "Medium," spatial ability scores also rise substantially, from 51.7 to a peak of 69.39. The scores then plateau for the "High" (65.51) and "Very High" (66.72) self-efficacy groups, which are all categorized as having "High" spatial ability.

Discussion

The analysis results provide an overview of the actual average spatial ability for each level of student self-efficacy. The findings show striking differences among each level of student self-efficacy. The average spatial ability of students with "Very Low" self-efficacy is estimated to be only 8.17, falling within the interval of -1.41 to 17.73. This value indicates that this group explicitly has very low spatial ability. This is significantly different from the other groups.

Meanwhile, students with "Low" self-efficacy have an average spatial ability score of 51.7, within the interval of 31.82 to 71.58, and in the "Medium" self-efficacy group, the average spatial ability increases to 69.4, within the interval of 63.23 to 75.55. The group of students with "High" self-efficacy has an average spatial ability of 65.51, which is in the interval of 63.39 to 67.63. The average spatial ability for students with "Very High" self-efficacy is slightly higher at 66.72, in the interval of 64.04 to 69.40.

This pattern indicates that an increase in self-efficacy correlates with an increase in students' spatial ability, although at the "High" and "Very High" self-efficacy levels, there is a tendency to plateau (a decrease in the rate of improvement). This slowing rate of improvement may occur because student engagement in learning is self-regulated and whether or not students are engaged is closely related to their own level of self-efficacy (Pintrich & De Groot, 1990). This means that students who have high confidence in their abilities will be more motivated and more actively use learning strategies that support cognitive achievement, such as spatial ability. However, self-efficacy alone is not enough. To achieve optimal learning outcomes, an integration of will (motivation) and skill (self-regulated learning) is required, so that students are not only confident but also possess effective learning strategies for solving spatial problems (Alafgani & Purwandari, 2019).

Schunk (2012) in his book also states that students with high self-efficacy solve more problems correctly and choose to rework more problems compared to students with low self-efficacy. This theory provides a strong reason why students at the "High" to "Very High" self-efficacy levels may perform better on mathematics tests, which in this case is a spatial ability test. Furthermore, Bandura (1997) also states that self-efficacy influences how students think, feel, and act in the learning process, including the application of effective strategies in mathematics. Students' belief in their own abilities is proven to facilitate more active engagement in higher-order thinking processes like spatial ability.

The variation in the average spatial ability scores at each self-efficacy level is confirmed by the results of the analysis on the differences in spatial ability based on student self-efficacy levels, which revealed that there is a significant difference in spatial ability when viewed from the level of self-efficacy. This significant difference occurs between the group of students with "Very Low" self-efficacy and all other groups with "Low," "Medium," "High," and "Very High" self-efficacy ($p<0.05$). In contrast, among the student groups with "Low," "Medium," "High," and "Very High" self-efficacy, no significant difference was shown ($p>0.05$). These results indicate that students with "Very Low" self-efficacy also obtained low results on the spatial ability test, whereas students with self-efficacy levels from "Low" to "Very High" obtained spatial ability test results that were considered statistically the same.

This difference can be explained through the theory of self-efficacy proposed by Bandura (1997), which states that individuals with very low levels of self-efficacy tend to be unsure of their abilities, feel easily distressed, and give up quickly when facing difficulties. This condition impacts motivation, leading to minimal effort and a tendency to avoid challenges, including solving spatial ability test problems. In the context of this study, students with "Very Low" self-efficacy seemingly could not solve the spatial ability test problems well, thus obtaining lower scores than the other groups.

This phenomenon can be analyzed more deeply through the four main sources of self-efficacy according to Bandura (1997): mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states. Students with "Very Low" self-efficacy levels likely have not had sufficient mastery experiences (experiences of success) in completing spatial tasks. When individuals experience failure without any small successes, they form negative beliefs about their own abilities.

This group may also not receive enough encouragement or verbal support from parents, such as praise or assurance that they can solve complex problems. This could be due to differences in students' family backgrounds. Additionally, students at this "Very Low" self-efficacy level might experience high levels of anxiety, pressure, or tension when facing the spatial ability test, which can interfere with their focus and problem-solving process. However, in this case, vicarious experience cannot be cited as a reason for the difference in spatial ability at the "Very Low" self-efficacy level because this research was conducted in the city of Yogyakarta, which is well-known for its students' high enthusiasm for learning.

Meanwhile, for the groups of students with self-efficacy levels ranging from "Low" to "Very High," the achievement in spatial ability did not differ significantly, indicating that the four sources of self-efficacy have developed to a sufficient level to support their performance. Although there may be variations in their level of self-confidence, the presence of mastery experiences from previous learning successes, vicarious experiences through observing successful models, and more intensive social persuasion in the form of social support allows them to maintain a relatively stable performance. Additionally, more controlled emotional states (emotional regulation) make them better prepared to complete visuospatial tasks.

High self-efficacy also helps students manage their emotions, set learning goals, and apply effective learning strategies (Bandura, 1995). High self-efficacy enables students to effectively manage their learning strategies, including the visualization strategies that are crucial for spatial problem-solving (Zimmerman, 2000). Thus, very low self-efficacy becomes a significant differentiating factor in students' spatial ability achievement. Therefore, strengthening self-efficacy is a strategic step in improving students' spatial achievement in school; for instance, providing positive feedback and teacher modeling can enhance spatial ability achievement (Schunk, 2012).

Conclusion

In terms of spatial ability, there is a significant difference between the student group with a "Very Low" self-efficacy level and all groups with "Low," "Medium," "High," and "Very High" self-efficacy levels. However, the average spatial abilities among the "Low," "Medium," "High," and "Very High" self-efficacy levels are considered statistically the same.

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