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The effect of learning styles on senior high school students' mathematical abstraction ability: A study at SMA N 11 Semarang

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Abstract

This study addresses the low level of mathematical abstraction ability among students at SMA Negeri 11 Semarang, as identified through a preliminary investigation. To overcome this issue, the Multi-Representation Discourse Model supported by performance-based assessment was employed to enhance students' abstraction capabilities. The primary objective of this research is to examine the influence of students' learning styles on their mathematical abstraction ability. A quantitative research approach was adopted, focusing on the relationship between learning styles and abstraction skills. Data were collected through an abstraction ability test, a learning style questionnaire, and interviews. The study population comprised Grade XI students at SMA Negeri 11 Semarang. A purposive sampling technique was utilized to select participants who had studied the topic of related angles, demonstrated active classroom participation, and possessed effective communication skills. The sample selected for this study was Class XI-10. The findings revealed a positive correlation between students' learning styles and their mathematical abstraction ability, with a correlation coefficient of 0.854, indicating a strong positive relationship. Furthermore, the coefficient of determination indicated that learning styles accounted for 73% of the variance in students' abstraction ability, while the remaining 27% was attributed to other factors. Based on these results, it can be concluded that learning styles have a significant and positive effect on students' mathematical abstraction thinking ability.

Keywords: Mathematical Abstraction Thinking Ability; Learning Styles.

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INTRODUCTION

Mathematics is a fundamental discipline as it serves as the foundation for various fields of science (Nisa, 2019; Setyowati et al., 2022). However, it is often considered difficult because of its abstract nature, which requires reasoning, problem-solving, and proof (Arafah et al., 2023; Kamil et al., 2021; Komala, 2018; Mawadah Putri Islamiati, 2022; Nurrahmah et al., 2022; Putra et al., 2023; Sumekar et al., 2019). Many students demonstrate varied responses when solving mathematical problems, ranging from being able to complete them to choosing to ignore them altogether (Setiyani et al., 2024). Learning approaches that emphasize rote memorization further increase these challenges, highlighting the need for instructional strategies that encourage students to construct ideas through more meaningful methods (Khasanah et al., 2019). In this regard, abstraction, as the process of forming concepts from experiences, becomes a key to understanding mathematics (Khasanah et al., 2021; Prabowo et al., 2022). This process enables students to move from concrete manipulation to abstract thinking (Prabowo et al., 2021; Prihandika et al., 2022), making the ability to think abstractly an essential skill to be mastered (Islam et al., 2021; Nisa, 2019; Nurrahmah et al., 2022; Putra et al., 2018; Sugandi et al., 2020).

Unfortunately, Indonesian students' mathematical abstraction ability is still relatively low, from elementary to higher education levels (Nihayah, 2021; Nurrahmah et al., 2022; Putra et al., 2018; Sugandi et al., 2020; Yusepa, 2017). Even developed countries such as South Korea continue to make efforts to improve this ability (Hong & Kim, 2016). The low level of abstraction is reflected in students' difficulties in manipulating mathematical objects, understanding relationships between concepts, making context-appropriate generalizations, and connecting concepts to real-life situations (Fitriani et al., 2018; Hong & Kim, 2016; Nihayah, 2021; Yusepa, 2017). A similar condition was found among eleventh-grade students at SMA Negeri 11 Semarang, who experienced difficulties in sketching problems, identifying object characteristics, and applying the concept of an altitude line in the topic of related angles, which led to failure in answering subsequent questions regarding the number of triangles formed.

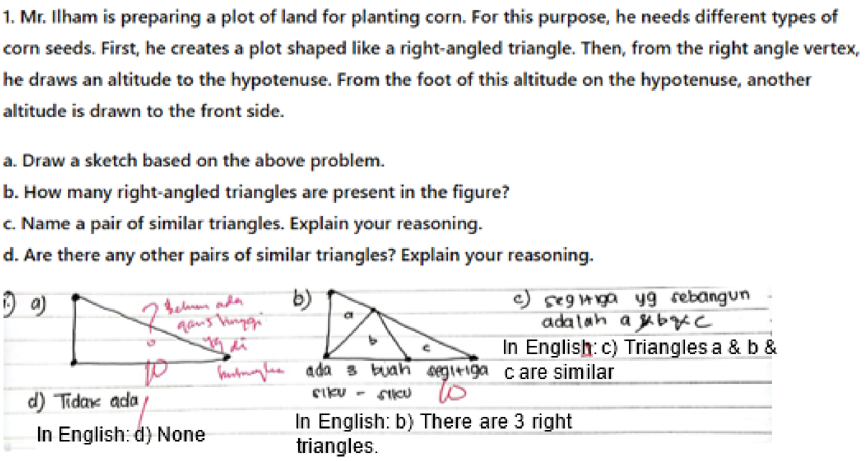

Figure 1. Sample of Students' Work Results

The low level of students' mathematical abstraction ability is caused by habits of solving problems without systematic steps, limited concept-based reasoning, a tendency to provide direct numerical answers, and neglect in explaining the stages of mathematical arguments (Khasanah et al., 2021). Moreover, students are required to think symbolically and imaginatively when solving problems, which poses its own challenges (Hong & Kim, 2016). Difficulties also arise because students are not accustomed to sketching problems and lack mastery of concepts from previously taught material, in line with Nurhikmayati (2017), who found that conceptual understanding is the main barrier to abstract thinking. Several studies have shown an increasing interest in mathematical abstraction, particularly in relation to learning styles (Faizah, 2016; Fajriah & Susanah, 2022; Natonis et al., 2022; Nurrahmah et al., 2021; Rosmiati & Ratnaningsih, 2021). Learning styles influence abstract thinking skills as they relate to how students process information to generalize, analyze, and draw conclusions from non-concrete concepts (Faizah, 2016; Fajriah & Susanah, 2022; Nurrahmah et al., 2021). Rosmiati & Ratnaningsih (2021) further emphasized that the alignment between learning styles and student abilities positively impacts academic achievement.

Learning style refers to the unique and consistent ways students absorb and process information (Purwanto et al., 2020). According to Piaget's cognitive development theory, abstraction ability develops through active exploration and reflection on experiences (Cerovac & Keane, 2024). The visual, auditory, and kinesthetic (VAK) learning styles facilitate this process in different ways: visual learners respond well to images and diagrams, auditory learners benefit from discussions and verbal explanations, while kinesthetic learners learn best through direct experience and experimentation. Anggriani et al., (2024) also reported a significant positive correlation between learning styles and representational abilities, including abstraction processes, thereby highlighting the influence of learning styles on abstraction skills.

Mathematical abstraction is a crucial prerequisite for understanding advanced mathematical concepts; however, various studies show that Indonesian students still perform poorly in this domain. Low abstraction ability is often indicated by difficulties in connecting representations, making generalizations, and manipulating symbols. Learning styles play a role in shaping how students process information and construct concepts, while multi-representational approaches are known to enhance conceptual understanding. Nevertheless, studies that simultaneously examine the relationship between learning styles and abstraction ability within the Multi-Representation Discourse (DMR) model integrated with performance assessment remain limited. This research addresses that gap by demonstrating that learning styles significantly contribute to students' abstraction ability, focusing on Grade XI students at SMA Negeri 11 Semarang.

Therefore, the present study's objective is to examine the influence of students' learning styles on their mathematical abstraction ability.

METHODS

This study employed a quantitative research method focusing on the influence of learning styles. The research used a quantitative approach with a quasi-experimental design, specifically the Nonequivalent Control Group Design (Sugiyono, 2018). The design involved two groups: class XI-10 as the experimental group, which received instruction through the Multi-Representation Discourse (DMR) model assisted by performance assessment, and class XI-8 as the control group, which received conventional instruction. The sample was selected using purposive sampling, considering academic ability equivalence and the availability of instructional schedules. Prior to the treatment, both groups were given a pretest to measure their initial mathematical abstraction ability. Subsequently, the experimental group underwent learning with the DMR model assisted by performance assessment, while the control group was taught using conventional methods. After the learning process, both groups were administered a posttest to measure improvements in mathematical abstraction ability.

Data were collected through a mathematical abstraction ability test using five indicators adapted from Mukhtar (2013), chosen to suit the objectives of this study, namely:

1. representing mathematical ideas in language and symbols,
2. identifying the characteristics of objects that are manipulated or imagined,
3. applying concepts in appropriate contexts,
4. establishing connections between processes or concepts to form understanding,
5. manipulating abstract mathematical objects.

The test instruments were validated and tested for consistency using Rasch analysis. Additional data collection instruments included a learning style questionnaire and interviews. The study population comprised all eleventh-grade students of SMA Negeri 11 Semarang in the 2024/2025 academic year. The sample was selected purposively to include students who, in the even semester of the 2024/2025 academic year, were learning relational angles, actively participated in class, and communicated effectively. The selected sample consisted of class XI-10 of SMA Negeri 11 Semarang. The data obtained were analyzed using simple linear regression with the assistance of SPSS 26.0. Prior to regression analysis, the data were tested for assumptions, namely residual normality and linearity tests. The example of test instruments can be shown in Figure 2.

1. Aji wants to determine the height of a two-story multipurpose building at his school without measuring it directly. If the distance between Aji and the building is 10 m with an elevation angle of 35°, and the height of Aji's eyes from the ground is 1.76 m (**sin 55° = 0.8** and **tan 55° = 1.4**):

a. Sketch the problem described above.
b. What steps would Aji take to determine the height of the building without measuring it?
c. Explain how to determine the height of the building.
d. If the situation is reversed, where the building is 0.9 m shorter than the height previously obtained and the elevation angle formed between Aji and the building is 30°, explain how to determine the distance between Aji and the building.

2. Two children observe the top of a tree from opposite positions. If the first child observes it at an elevation angle of 60° and the second child at 30°, and the distance between the two children is 100 m (the tree is not positioned exactly in the middle between them), with the height of their eyes from the ground being 1.5 m (**√3 ≈ 1.7**):

a. Draw a sketch of the problem and provide labels on the sketch.
b. Explain how to determine the height of the tree.

3. A pilot in an airplane observes the top of a mountain from an altitude of 1100 m, with the elevation angle (angle of observation from the horizontal) being 30°:

a. Draw a sketch showing the mountain peak, the airplane's position, and the altitude from the ground, with proper labels.
b. Determine the distance from the airplane to the mountain peak.

Figure 2. The Test Instruments and Indicators of Students' Abstract Thinking Ability

RESULTS AND DISCUSSION

The sixth hypothesis testing was carried out through a series of regression analyses, including the determination of the regression equation, the significance test of the regression, the correlation coefficient test, and the determination of the coefficient of determination. The type of analysis used was simple linear regression, with learning style questionnaire results as the independent variable (X), which is categorical, and students' mathematical abstraction ability as the dependent variable (Y), which is numerical. Before conducting the regression analysis, the categorical data of the learning style variable were converted into ordinal data. The regression testing was performed using SPSS version 26.0 software and was preceded by classical assumption tests, namely the normality test of residuals and the linearity test.

1. Test of Residual Normality

The normality test aims to determine whether the data distribution comes from a normally distributed population or not. The hypotheses used in this test are as follows

H_0 : The data obtained from the learning style questionnaire are drawn from a normally distributed population

H_1: The data obtained from the learning style questionnaire are drawn from a population that is not normally distributed.

Decision making in the normality test is based on the significance value (Sig.) obtained from the analysis; the null hypothesis (H_0) is accepted if Sig. > 0.05, which indicates that the data are normally distributed. The output of the normality test for the questionnaire data is presented in Table 1.

Table 1. Output of the Residual Normality Test Using SPSS 26.0

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		31
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	8.28042298
Most Extreme Differences	Absolute	.133
	Positive	.089
	Negative	-.133
Test Statistic		.133
Asymp. Sig. (2-tailed)		.170[c]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Based on the results of the normality test on the questionnaire data, a significance value of sig = 0.170 was obtained, which is greater than the significance threshold of 0.05. According to the testing criteria, this indicates that the null hypothesis (H_0) is accepted. Thus, it can be concluded that the learning style questionnaire data come from a normally distributed population.

2. Test of Linearity

The linearity test aims to examine whether the relationship between the independent variable (X) and the dependent variable (Y) statistically follows a linear pattern. The existence of a significant linear relationship is an important prerequisite in linear regression analysis, indicating that the regression model constructed is appropriate for predicting the dependent variable. The regression linearity test was conducted to evaluate whether there is a linear relationship between the learning style variable and the mathematical abstraction ability variable. The purpose of this test is to ensure that the learning style variable statistically influences students' mathematical abstraction ability through a linear relationship pattern. The hypotheses used in this test are as follows:

H_0: $b = 0$, which states that there is no linear relationship between learning styles and students' mathematical abstraction thinking ability (non-linear model)

H_1: $b \neq 0$, which states that there is a linear relationship between learning styles and students' mathematical abstraction ability (linear model).

The decision-making criterion in the linearity test is that if the significance value of the Deviation from Linearity component is greater than 0.05 (Sig. > 0.05), then H_0 is rejected; conversely, if the significance value of the Deviation from Linearity is less than 0.05 (Sig. < 0.05), H_0 is accepted. The output results of the linearity test using SPSS 26.0 are presented in Table 2.

Table 2. Output of the Linearity Test Using SPSS 26.0

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Experimental Class Posttest * learning style	Between Groups	(Combined)	221.177	2	110.588	1.528	.234
		Linearity	190.522	1	190.522	2.633	.116
		Deviation from Linearity	30.655	1	30.655	.424	.520
	Within Groups		2026.307	28	72.368		
	Total		2247.484	30			

Based on the results in the table below, the significance value of Deviation from Linearity was 0.520, which exceeds the significance level of 0.05. Thus, it can be concluded that there is a linear relationship between learning styles and students' mathematical abstraction ability.

The results of the classical assumption tests showed that the residuals were normally distributed and that a relationship exists between learning styles and mathematical abstraction ability. Therefore, the analysis could be continued to the multiple linear regression test stage.

3. The Regression Equation

The regression analysis was conducted using SPSS 26.0, in which the regression equation was obtained from the Coefficients table, as presented in Table 3.

Table 3. *Output Coefficient*

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	2.284	9.529		.240	.812
	Learning style	1.187	.134	.854	8.832	.000

a. Dependent Variable: posttest experiment class

Based on the results in Table 3, the linear regression equation obtained is $\hat{Y} = 2.284 + 1.187X$. This equation shows that the constant (a) is 2.284, meaning that if the value of learning style (X) is 0, the predicted value of students' mathematical abstraction ability (Y) is 2.284. The regression coefficient of 1.187 indicates that every one-unit increase in students' learning style score is followed by an increase of 1.187 units in mathematical abstraction ability. Since the regression coefficient (b) is positive, it can be concluded that learning styles have a positive effect on students' mathematical abstraction ability. According to Piaget's theory of cognitive development, learning styles that support exploration and reflection can accelerate the development of abstraction ability.

4. Test of Regression Significance

The regression significance test aims to determine the level of significance of the simultaneous effect of the independent variables on the dependent variable. This effect can be examined by referring to the significance value in the ANOVA table of the multiple regression analysis output, with the hypotheses formulated as follows.

$H_0 : \beta = 0$ There is no significant effect of learning styles on students' mathematical abstraction ability in multi-representation discourse learning assisted by performance assessment (the regression coefficient is not significant).

$H_1 : \beta \neq 0$ There is a significant effect of learning styles on students' mathematical abstraction ability in multi-representation discourse learning assisted by performance assessment (the regression coefficient is significant).

The testing criterion is to accept H_0 if the significance value (sig) > 0.05, and reject it otherwise. The results of the regression significance test using SPSS 26.0 can be seen in Table 4.

Table 4. Output of ANOVA

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1638.348	1	1638.348	77.999	.000[b]
	Residual	609.136	29	21.995		
	Total	2247.484	30			

a. Dependent Variable: posttest of the experiment class

b. Predictors: (Constant), learning style

Based on the calculation results, the significance value obtained was 0.000, which is less than 0.05; therefore, H_0 is rejected. This indicates that learning styles have a significant effect on students' mathematical abstraction ability in multi-representation discourse learning assisted by performance assessment (as reflected in the regression coefficient). Learning styles significantly influence abstraction ability because their alignment with the Multi-Representation Discourse (DMR) model allows students to more easily explore and reflect on various representations, in line with Piaget's cognitive development principles (Cerovac & Keane, 2024). This alignment enhances motivation, active engagement, and conceptual understanding, thereby optimally supporting the development of mathematical abstraction ability.

5. Test of the Correlation Coefficient

The correlation coefficient test aims to identify the strength of the relationship between learning styles and students' mathematical abstraction ability, with the result expressed as a numerical value known as the correlation coefficient. The results of the correlation coefficient test using SPSS 26.0 can be seen in Table 5.

Table 5. Output Model Summary

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.854[a]	.729	.720	4.583086
a. Predictors: (Constant), learning style				

Referring to the Model Summary in Table 5, the correlation coefficient (R) obtained was 0.854. This value indicates a positive relationship between learning styles and mathematical abstraction ability, and the strength of this relationship falls into the "very strong" category. Natonis et al. (2022) stated that learning styles are related to abstraction ability because the way students process information affects their capacity to generalize, analyze, and draw conclusions about abstract concepts. Therefore, the positive relationship between learning styles and abstraction ability arises from the alignment of learning styles, which enables students to more easily understand and connect various representations presented within the Multi-Representation Discourse (DMR) model.

6. The Coefficient of Determination

Coefficient The coefficient of determination (R^2) measures the proportion of variability in the dependent variable that can be explained by the independent variable in the regression model. Based on the analysis in the Model Summary table, the R^2 value obtained was 0.729, indicating that 73% of the variation in students' mathematical abstraction ability can be explained by learning styles through the regression model $\hat{Y} = 2.284 + 1.187X$. The remaining 27% of the variability is explained by other factors.

The relationship between learning styles and students' mathematical abstraction ability was further confirmed by the sixth hypothesis test, namely the simple linear regression analysis. The results showed that the linearity test indicated a linear relationship between learning styles and mathematical abstraction ability. The regression equation obtained was $\hat{Y} = 2.284 + 1.187X$. This equation shows that the constant (a) is 2.284, meaning that if the value of learning style is 0, the predicted value of mathematical abstraction ability is 2.284. The regression coefficient of 1.187 indicates that each one-unit increase in learning style score is followed by an increase of 1.187 units in mathematical abstraction ability. Since the regression coefficient is positive, it can be concluded that learning styles have a positive effect on students' mathematical abstraction ability. Moreover, the significance test results confirmed that this effect is statistically significant. This finding is also reflected in the correlation coefficient of 0.854, which indicates a strong positive relationship between learning styles and mathematical abstraction ability. Furthermore, the coefficient of determination shows that learning styles account for 73% of the variance in mathematical abstraction ability, while the remaining 27% is influenced by other factors.

Based on these results, it can be concluded that learning styles have a positive effect on students' mathematical abstraction ability. This finding supports the statement of Anggriani et al. (2024), who argued that learning styles positively influence the development of abstraction processes, particularly in representation skills. It also aligns with Piaget's cognitive development theory, which emphasizes that learning styles that encourage exploration and reflection can accelerate the development of abstraction skills. In addition, Habeahan et al., (2024) reported that, besides learning styles, cognitive styles also significantly influence students' mathematical abstraction ability, making cognitive style one of the other factors affecting abstraction ability.

The influence of learning styles is also evident in the differences in abstraction abilities among students with different learning styles. The results showed that students with a visual learning style were able to meet all indicators of mathematical abstraction ability. Kinesthetic learners nearly fulfilled all indicators, although some were only achieved at a sufficient level, as they were not fully optimized. Meanwhile, auditory learners still showed limitations, particularly in the indicator related to identifying the characteristics of manipulated or imagined objects. Based on these findings, it can be concluded that learning styles affect students' mathematical abstraction ability, as reflected in the variation of abstraction abilities according to different learning styles. This is consistent with the findings of Faizah (2016) and Nurrahmah et al. (2021), who also concluded that abstraction ability differs depending on students' learning styles.

CONCLUSION

This study demonstrates that learning styles have a positive and significant influence on students' mathematical abstraction ability. The regression analysis indicates a linear relationship between the two variables, with learning styles contributing 73% to abstraction ability. Furthermore, differences in abstraction ability were found based on students' learning styles. Students with a visual learning style showed the highest level of ability, followed by kinesthetic learners, while auditory learners still exhibited limitations in certain indicators. Thus, learning styles significantly affect the level of achievement in students' mathematical abstraction ability.

This study has several limitations, including the limited number of participants, the use of instruments that primarily focused on measuring mathematical abstraction ability, the suboptimal implementation of the instructional model due to time constraints, and the lack of consideration for external factors such as the learning environment and technological support. Therefore, future research is recommended to involve a larger and more diverse sample, develop instruments that also capture non-cognitive aspects, implement the model over a longer period of time, integrate digital technologies tailored to students' learning styles, and examine the interplay between learning styles and ability levels to provide a more comprehensive basis for designing adaptive instructional strategies.

DECLARATIONS

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Conflict of Interest : The authors declare no conflict of interest.
Additional Information : This study was conducted using data collected from SMA N 11 Semarang, and permission to use the data was obtained from the institution. Additional information related to this study is available upon request.

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