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Learning Motivation as a Predictor of Mathematics Achievement: The Role of Visual, Auditory, Kinesthetic Learning Styles among Second Grade Angkasa Lanud Silas Papare Elementary School

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A B S T R A C T

Mathematics learning in elementary schools is essential for developing students' numeracy skills and foundational mathematical understanding. This study aimed to examine the effects of learning motivation and Visual–Auditory–Kinesthetic (VAK) learning styles on mathematics achievement among second-grade students at SD Angkasa Lanud Silas Papare. A quantitative ex post facto design with a correlational approach was employed. The participants consisted of 70 students selected through saturated sampling. Data on learning motivation and VAK learning styles were collected using validated and reliable questionnaires, while mathematics achievement data were obtained from test scores on addition and subtraction topics. Data were analyzed using descriptive statistics, classical assumption tests, and multiple linear regression. The results showed that learning motivation had a positive and significant effect on mathematics achievement ($\beta = 1.328$, $p < .001$), whereas visual, auditory, and kinesthetic learning styles did not have significant effects when analyzed simultaneously. The regression model explained 52.02% of the variance in mathematics achievement ($R^2 = .5202$). These findings indicate that learning motivation is a stronger predictor of mathematics achievement than VAK learning styles. Therefore, strengthening students' motivation should be prioritized to improve mathematics learning outcomes in elementary schools.

1. Introduction

Mathematics education at the elementary school level, particularly during Phase A of the Indonesian Merdeka Curriculum, plays a fundamental role in fostering children's numeracy development and foundational mathematical competencies (Fitria et al., 2021) During this stage, students are typically between seven and eight

years old and are generally transitioning through the concrete operational stage of cognitive development, as proposed by Piaget. At this developmental stage, children begin to think logically about concrete objects and real-life situations, although they still experience difficulties in understanding abstract concepts without the support of tangible representations and direct experiences (Handika et al., 2022).

A key characteristic of this developmental stage is children's ability to apply logical thinking to concrete objects and situations that can be directly observed and manipulated (Handika et al., 2022). However, elementary school students at this stage often experience difficulties in understanding abstract mathematical symbols and concepts when learning is not supported by concrete representations or visual learning media. Therefore, instructional approaches that provide tangible experiences and visualizations are essential for facilitating students' conceptual understanding and numeracy development (Muti'ah et al., 2024; Syahrir et al., 2025).

Students' success in mastering basic arithmetic concepts is strongly influenced by internal factors, particularly learning motivation. Learning motivation refers to the psychological drive that encourages students to actively engage in learning activities, sustain effort, and achieve academic goals. Students with higher levels of motivation tend to demonstrate greater persistence, concentration, and participation during learning, which positively contributes to their academic achievement (Edwana et al., 2023; Rizqi et al., 2025). Empirical evidence has consistently shown that learning motivation plays a crucial role in improving students' learning outcomes, including in mathematics and numeracy-related tasks (Susanti et al., 2025). On the other hand, the Visual–Auditory–Kinesthetic (VAK) learning style framework describes learners' preferences in receiving and processing information through visual, auditory, and kinesthetic modalities. These learning preferences are often considered in instructional design to facilitate students' engagement and understanding during the learning process (Supit et al., 2023).

However, the predominance of certain learning preferences, particularly visual learning, may be influenced by instructional practices that rely heavily on textbooks, written materials, demonstrations, and board-based explanations. Such classroom environments naturally provide greater exposure to visual stimuli, which may encourage students to adopt visual learning preferences regardless of their individual characteristics (Mustika et al., 2024). Previous studies have reported that although learning styles may be associated with academic performance, learning motivation often exerts a stronger influence on learning outcomes (Fasha et al., 2023; Rizqi et al., 2025). Furthermore, when learning motivation is considered simultaneously, differences in academic achievement among students with visual, auditory, and kinesthetic preferences tend to become less pronounced. This finding suggests that VAK learning styles may function primarily as preferred channels for receiving information rather than as determinants of students' intellectual capacity or academic success (Fasha et al., 2023).

Based on these considerations, this study investigates the influence of learning motivation and VAK learning styles on mathematics achievement among second-grade elementary school students. By employing multiple linear regression analysis, the study seeks to identify which factor contributes most significantly to students' achievement. Given the ongoing debate regarding the effectiveness of learning-style-based instruction, this research also provides empirical evidence on whether learning motivation or learning-style preferences serve as stronger predictors of mathematics achievement in elementary education.

2. Methodology

This study employed a quantitative approach using an ex post facto design with a correlational research framework. The study was conducted to examine the influence of learning motivation and Visual–Auditory–Kinesthetic (VAK) learning styles on mathematics achievement among second-grade students at SD Angkasa Lanud Silas Papare. The independent variables consisted of learning motivation, visual learning style, auditory learning style, and kinesthetic learning style, while mathematics achievement in addition and subtraction topics served as the dependent variable. The ex post facto design was considered appropriate because the variables under investigation had naturally occurred and were not manipulated by the researcher.

The study involved one dependent variable and four independent variables. The dependent variable was students' mathematics achievement (Y), measured through an achievement test on addition and subtraction topics. The independent variables consisted of learning motivation (X_1), visual learning style (X_2), auditory learning style (X_3), and kinesthetic learning style (X_4). Data on learning motivation and VAK learning styles were collected using validated questionnaires. Specifically, the learning motivation questionnaire was designed to assess students' motivational characteristics reflected in their persistence in learning, attention during classroom instruction, active engagement in learning activities, and willingness to complete mathematics tasks.

Data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics were employed to summarize the characteristics of the research variables, including mean, median, standard deviation, minimum score, and maximum score. Prior to hypothesis testing, several classical assumption tests were conducted, including the normality test, multicollinearity test, and heteroscedasticity test, to ensure that the regression model met the required assumptions. Hypothesis testing was performed using simple linear regression and multiple linear regression analyses to examine both the individual and simultaneous effects of learning motivation and VAK learning styles on students' mathematics achievement. All statistical analyses were conducted using R Studio software.

The population of this study consisted of all second-grade students enrolled at SD Angkasa Lanud Silas Papare during the 2024/2025 academic year. Since the total population comprised only 70 students, the study employed a saturated sampling

technique (total sampling), in which all members of the population were included as research participants. Consequently, the sample size was identical to the population size, resulting in a total of 70 students participating in the study. The use of saturated sampling was considered appropriate because it allowed the researcher to obtain comprehensive information from the entire target population and minimize sampling bias. This approach is commonly employed when the population size is relatively small and accessible for data collection.

3. Results and Discussion

Results

Descriptive Statistics

Descriptive statistical analysis was conducted to provide an overview of students' mathematics achievement, learning motivation, and VAK learning styles. The results are presented in Table 1.

Table 1. Descriptive Statistics of Research Variables

Variabel	N	Mean	Median	SD	Min	Max
Mathematics achievement	70	51,03	49,00	19,76	10	88
Learning motivation	70	73,74	72,50	11,07	53	95
Visual learning style	70	22,10	21,50	4,26	11	32
Auditory learning style	70	22,46	22,50	4,13	14	31
Kinesthetic learning style	70	20,46	20,00	4,46	12	32

The descriptive statistics indicate that students achieved an average mathematics score of 51.03, with scores ranging from 10 to 88. The relatively high standard deviation (SD = 19.76) suggests considerable variability in students' mathematics achievement. Learning motivation demonstrated the highest mean score among the independent variables (M = 73.74, SD = 11.07), indicating that students generally possessed a relatively high level of motivation toward learning. Meanwhile, the mean scores for visual, auditory, and kinesthetic learning styles were relatively similar, suggesting that students exhibited balanced learning-style preferences. The comparison between mean and median values across all variables revealed only minor differences, indicating that the distributions were approximately symmetrical.

Classical Assumption Test

Normality Test

The normality assumption was examined using the Shapiro–Wilk test. The analysis yielded a significance value of p = 0.992, which exceeded the threshold of 0.05.

Therefore, the residuals were normally distributed. Furthermore, the Normal Q–Q Plot showed that the residual points closely followed the diagonal reference line in Figure 1, providing additional evidence that the residuals met the normality assumption.

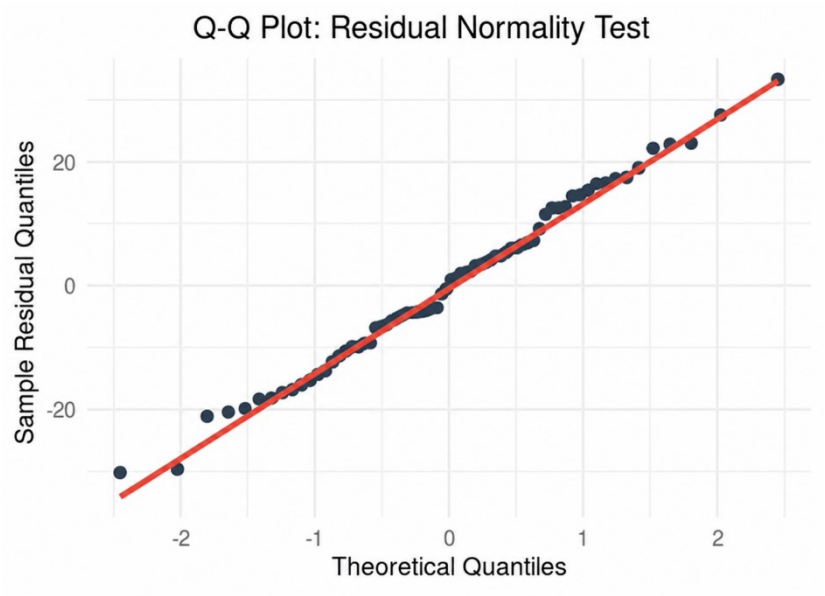

Figure 1. Graphic Normality Test

Multicollinearity Test

Prior to conducting the multiple linear regression analysis, a multicollinearity test was performed to ensure that the independent variables were not highly correlated with one another. The Variance Inflation Factor (VIF) was used to evaluate the presence of multicollinearity, as excessive intercorrelations among predictors may affect the stability and interpretation of the regression coefficients. The results of the multicollinearity assessment are presented in Table 2.

Table 2. Multicollinearity Test Results

Variable	VIF
Learning motivation	1.342
Visual learning style	1.284
Auditory learning style	1.197
Kinesthetic learning style	1.439

All independent variables exhibited Variance Inflation Factor (VIF) values substantially below the threshold of 10, indicating the absence of multicollinearity. Therefore, the predictors included in the regression model did not demonstrate excessive intercorrelations that could distort coefficient estimates. This finding suggests that each independent variable explained a distinct portion of the variance in mathematics achievement, enabling reliable estimation and interpretation of the regression coefficients.

Heteroscedasticity Test

The Breusch–Pagan test was employed to examine heteroscedasticity. The analysis produced a Breusch–Pagan statistic of 10.865 with a significance value of p = 0.028. Since the p-value was less than .05, the model exhibited heteroscedasticity, indicating that the variance of residuals was not constant across observations. Nevertheless, the regression coefficients remained unbiased and interpretable, although caution was exercised when interpreting standard errors.

Simple Linear Regression Analysis

Effect of Learning Motivation on Mathematics Achievement

A simple linear regression analysis was performed to investigate the influence of learning motivation on mathematics achievement. The regression results, including the regression coefficient (B), standard error (SE), t-value, and p-value, are presented in Table 3 to evaluate the predictive effect of learning motivation on students' mathematics achievement.

Table 3. Simple Regression Results for Learning Motivation

Variable	B	SE	t	p
Constant	-40.991	11.536	-3.553	< 0.001
Learning Motivation	1.248	0.155	8.065	< 0.001

The resulting regression equation was:

$$Y = -40.991 + 1.248X_1$$

The coefficient of determination (R^2) was 0.4889, indicating that learning motivation explained 48.89% of the variance in mathematics achievement.

Effect of Visual Learning Style on Mathematics Achievement

A simple linear regression analysis was performed to examine the influence of visual learning style on mathematics achievement. The regression results, including the regression coefficient (B), standard error (SE), t-value, and p-value, are presented in Table 4 to evaluate the predictive effect of visual learning style on students' mathematics achievement.

Table 4. Simple Regression Results for Visual Learning Style

Variable	B	SE	t	p
Constant	19.231	12.034	1.598	0.115
Visual learning style	1.439	0.535	2.690	0.009

The resulting regression equation was:

$$Y = 19.231 + 1.439X_2$$

The model produced an R^2 value of 0.0962, indicating that visual learning style accounted for 9.62% of the variance in mathematics achievement.

Effect of Auditory Learning Style on Mathematics Achievement

A simple linear regression analysis was performed to investigate the relationship between auditory learning style and mathematics achievement. The regression results, including the regression coefficient (B), standard error (SE), t-value, and p-value, are presented in Table 5 to evaluate the predictive effect of auditory learning style on students' mathematics achievement.

Table 5. Simple Regression Results for Auditory Learning Style

Variable	B	SE	t	p
Constant	35.565	13.096	2.716	0.008
Auditory learning style	0.689	0.574	1.200	0.234

The resulting regression equation was:

$$Y = 35.565 + 0.689X_3$$

The model produced an R^2 value of 0.0207, indicating that auditory learning style accounted for 2.07% of the variance in mathematics achievement.

Effect of Kinesthetic Learning Style on Mathematics Achievement

To examine the effect of kinesthetic learning style on mathematics achievement, a simple linear regression analysis was conducted. The analysis estimated the regression coefficient, standard error, t-value, and significance level to determine whether kinesthetic learning style significantly predicted students' mathematics achievement. The results of the analysis are presented in Table 6.

Table 6. Simple Regression Results for Kinesthetic Learning Style

Variable	B	SE	t	p
Constant	31.203	10.988	2.840	0.006
Kinesthetic learning style	0.969	0.525	1.846	0.069

The resulting regression equation was:

$$Y = 31.203 + 0.969X_4$$

The model produced an R^2 value of 0.0477, indicating that kinesthetic learning style accounted for 4.77% of the variance in mathematics achievement.

Multiple Linear Regression Analysis

Multiple linear regression analysis was performed to determine the influence of learning motivation and learning styles (visual, auditory, and kinesthetic) on students' mathematics achievement. The results of the regression analysis, including the regression coefficients (B), standard errors (SE), t-values, and significance levels (p-values), are presented in Table 7.

Table 7. Results of Multiple Linear Regression Analysis

Variable	B	SE	t	p
Constant	-40.882	13.639	-2.997	0.004
Learning motivation	1.328	0.178	7.476	< 0.001
Visual learning style	0.659	0.452	1.460	0.149
Auditory learning style	-0.227	0.449	-0.505	0.615
Kinesthetic learning style	-0.756	0.457	-1.654	0.103

The resulting regression model can be expressed as follows:

$$Y = -40.882 + 1.328X_1 + 0.659X_2 - 0.227X_3 - 0.756X_4$$

The results indicated that learning motivation was the only variable that significantly predicted mathematics achievement ($p < 0.001$). In contrast, visual, auditory, and kinesthetic learning styles did not demonstrate statistically significant effects ($p > 0.05$).

Coefficient of Determination

The multiple regression model produced a coefficient of determination (R^2) of 0.5202. This finding indicates that learning motivation and VAK learning styles collectively explained 52.02% of the variance in students' mathematics achievement. The remaining 47.98% may be attributed to other factors not examined in this study, such as instructional strategies, family environment, prior mathematical knowledge, and students' cognitive abilities.

Discussion

The Effect of Learning Motivation on Mathematics Achievement

The findings revealed that learning motivation had a positive and statistically significant effect on students' mathematics achievement. The regression analysis demonstrated that learning motivation was the strongest predictor among all independent variables examined in this study. Furthermore, learning motivation alone explained 48.89% of the variance in students' mathematics achievement, indicating its substantial contribution to learning outcomes. This finding supports motivational theories that emphasize the role of psychological drive in determining students' engagement and academic success. Learning motivation encourages students to participate actively in classroom activities, maintain attention during

instruction, and persist in solving challenging mathematical problems. Students with higher motivation tend to invest greater effort in learning tasks and are more likely to achieve better academic outcomes (Jehadus et al., 2022).

These findings may also be understood through students' learning behaviors during mathematics instruction. Students with higher learning motivation are more likely to maintain attention during teacher explanations, persist in completing mathematics tasks, and engage actively in classroom learning activities. Within different learning preferences, motivated visual learners tend to benefit from diagrams, symbols, and other visual representations; motivated auditory learners are more likely to engage by listening carefully and participating in classroom discussions; whereas motivated kinesthetic learners tend to sustain their engagement through hands-on activities and the use of concrete learning materials. These behavioral characteristics help explain how learning motivation supports mathematics achievement across different learning preferences rather than through learning style alone (Xia et al., 2022).

The results are consistent with previous studies reporting that learning motivation significantly influences academic achievement across various educational contexts. For example, Gumala et al. (2023) found that motivated students demonstrate higher levels of participation and engagement during classroom learning. Similarly, Vidianti et al. (2022) reported that learning motivation positively contributes to mathematics achievement among elementary school students. Recent evidence also suggests that instructional approaches designed to enhance students' motivation can improve learning outcomes and numeracy performance (Rizqi et al., 2025). From a developmental perspective, the findings can also be explained through Piaget's theory of cognitive development. Students in second grade generally belong to the concrete operational stage, during which learning effectiveness depends heavily on active engagement with meaningful learning experiences. Motivation serves as an important catalyst that encourages students to interact with learning materials, explore mathematical ideas, and participate in problem-solving activities. Consequently, students with higher motivation are more likely to develop a deeper understanding of mathematical concepts.

The Effect of Visual Learning Style on Mathematics Achievement

The results indicated that visual learning style showed a positive relationship with mathematics achievement in the simple regression analysis. However, its effect became statistically non-significant when analyzed together with learning motivation and other learning-style variables in the multiple regression model. One possible explanation is that elementary school mathematics instruction frequently relies on visual representations such as numbers, symbols, diagrams, pictures, and written explanations (Laili et al., 2025). As a result, many students become accustomed to processing information visually regardless of their preferred learning style, particularly when instructional activities emphasize the visualization of abstract concepts through concrete learning media (Syahrir et al., 2025). Therefore, the observed influence of visual learning preference may reflect instructional practices rather than a unique cognitive advantage associated with visual learners.

This finding aligns with contemporary educational research suggesting that learning styles function primarily as preferences for receiving information rather than determinants of academic performance. Supit et al. (2023) reported that although students exhibit different learning-style preferences, these differences do not necessarily translate into substantial variations in learning achievement. Similarly, recent studies emphasize that instructional quality and student engagement exert stronger effects on academic performance than learning-style preferences alone. From Piaget's perspective, visual materials may facilitate learning because they provide concrete representations that help students understand mathematical concepts. Nevertheless, the effectiveness of these representations depends more on how students actively engage with the learning process than on their individual learning-style preferences.

The Effect of Auditory Learning Style on Mathematics Achievement

The findings demonstrated that auditory learning style did not significantly influence students' mathematics achievement. Although the regression coefficient was positive, the relationship was not statistically significant. Mathematics learning requires not only listening to explanations but also understanding concepts, reasoning logically, and applying procedures to solve problems. Therefore, the ability to process information through auditory channels alone may not be sufficient to improve mathematics achievement. Students must also engage cognitively with mathematical tasks through practice, reflection, and problem-solving activities.

This finding supports the argument that motivation plays a more important role than learning-style preferences in determining academic success. Fasha et al. (2023) reported that motivated students tend to achieve higher mathematics scores regardless of their preferred learning style. Likewise, Simanullang et al. (2024) found that learning motivation contributed more substantially to mathematics achievement than VAK learning styles. The result also reflects Piaget's view that children in the concrete operational stage learn most effectively through direct interaction with concrete objects and experiences. Listening alone may not provide sufficient support for developing mathematical understanding unless accompanied by meaningful learning activities and concrete representations.

The Effect of Kinesthetic Learning Style on Mathematics Achievement

The analysis showed that kinesthetic learning style was not a significant predictor of mathematics achievement. Although the regression coefficient suggested a positive tendency in the simple regression model, the effect disappeared when learning motivation and other variables were considered simultaneously. This finding may indicate that students' preference for physical activity and hands-on learning does not automatically translate into higher mathematics achievement. Instead, the effectiveness of kinesthetic experiences depends on how these activities are integrated into instructional practices and aligned with learning objectives.

Nevertheless, kinesthetic approaches remain important for elementary school students because they provide opportunities to interact directly with concrete

materials. Piaget's theory emphasizes that children in the concrete operational stage learn more effectively when abstract concepts are connected to tangible experiences. Therefore, kinesthetic activities can still support conceptual understanding even though they may not independently predict achievement outcomes. Recent studies have shown that instructional media and learning activities involving concrete experiences can improve students' understanding of mathematical concepts and numeracy skills (Muti'ah et al., 2024; Oktama et al., 2026). However, the present findings suggest that students' motivational characteristics remain more influential than their preferred learning modalities.

The Simultaneous Effect of Learning Motivation and VAK Learning Styles on Mathematics Achievement

The multiple regression analysis revealed that learning motivation and VAK learning styles collectively explained 52.02% of the variance in mathematics achievement. However, among all predictors included in the model, only learning motivation demonstrated a statistically significant effect. This finding suggests that although learning styles may contribute to students' learning experiences, motivation remains the primary factor influencing mathematics achievement. Students who are highly motivated tend to pay greater attention during lessons, demonstrate stronger persistence when encountering difficulties, and engage more actively in learning activities. These behaviors ultimately contribute to better academic performance.

The results support contemporary perspectives that question the effectiveness of learning-style-based instruction as a primary strategy for improving achievement. Recent reviews indicate that educational interventions should focus more on enhancing students' motivation, engagement, and self-regulated learning rather than attempting to match instruction exclusively to learning-style preferences (Cuevas & Dawson, 2018). Overall, the findings indicate that learning motivation serves as the dominant predictor of mathematics achievement among second-grade elementary students. Therefore, efforts to improve mathematics learning outcomes should prioritize instructional strategies that foster motivation, active participation, and meaningful learning experiences while still accommodating diverse learning preferences.

The present findings also help explain the inconsistent evidence reported in previous studies regarding the role of VAK learning styles. While some studies have reported significant associations between learning styles and academic achievement, the current findings indicate that these effects become less apparent when learning motivation is considered simultaneously. This difference may be related to the characteristics of second-grade elementary students, who are still in the concrete operational stage and tend to use multiple sensory modalities simultaneously during mathematics learning (Handika et al., 2022). Consequently, learning motivation appears to play a more substantial role than any single preferred learning style. This suggests that learning styles may function primarily as students' preferred modes of receiving information, whereas learning motivation represents the internal psychological drive that determines the extent to which students engage

with learning tasks. Therefore, the present study contributes to the growing evidence that strengthening students' learning motivation may have a greater impact on mathematics achievement than focusing exclusively on matching instructional practices to specific learning-style preferences.

From a psychopedagogical perspective, learning motivation appears to facilitate mathematics achievement by strengthening students' cognitive and behavioral engagement during learning rather than by altering their preferred learning modality (Jonivan & Suhirman, 2026). Motivated students are more likely to sustain attention, persist when encountering challenging mathematical problems, and complete learning tasks regardless of whether they primarily learn through visual, auditory, or kinesthetic experiences. In this context, learning styles may influence how students prefer to access learning materials, whereas learning motivation determines the intensity of their engagement with those learning experiences. Consequently, motivation functions as the underlying psychological mechanism that enables students to make effective use of their preferred learning approaches to achieve better mathematics outcomes.

4. Conclusion

Based on the findings and data analysis, it can be concluded that learning motivation has a positive and significant effect on the mathematics achievement of second-grade students at SD Angkasa Lanud Silas Papare, particularly in addition and subtraction topics. Students with higher levels of learning motivation tended to achieve better mathematics learning outcomes, indicating that motivation plays an important role in supporting academic success. The results also revealed that visual learning style demonstrated a positive effect on mathematics achievement in the simple regression analysis. However, auditory and kinesthetic learning styles did not show significant effects on students' mathematics achievement. These findings suggest that differences in learning-style preferences are not the primary determinants of mathematics achievement among elementary school students.

Furthermore, learning motivation and VAK learning styles collectively explained 52.02% of the variance in mathematics achievement. Nevertheless, learning motivation emerged as the most influential predictor compared with visual, auditory, and kinesthetic learning styles. This indicates that motivational factors contribute more substantially to students' mathematics performance than learning-style preferences. The findings highlight the importance of fostering students' learning motivation in elementary mathematics classrooms. Therefore, teachers are encouraged to design engaging, interactive, and meaningful learning experiences that align with students' developmental characteristics. Such instructional practices may enhance students' participation, confidence, and enthusiasm for learning, ultimately leading to improved mathematics achievement.

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