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RELATIONSHIPS AMONG MATHEMATICAL REASONING, SCIENTIFIC INQUIRY, AND ACADEMIC ACHIEVEMENT

[1]Dairo Abiodun Johnson, [2]Odusote Oluwatoyin Idowu, & [3]Osiyemi Ajoke Oladele

[1]Department of Mathematics, Sikiru Adetona College of Education, Science and Technology, Omu Ajose, Ogun State, Nigeria

[2]Department of Biology, Sikiru Adetona College of Education, Science and Technology, Omu Ajose, Ogun State, Nigeria

[3]Department of Physics, Sikiru Adetona College of Education, Science and Technology, Omu Ajose, Ogun State, Nigeria

Correspondence E-mail: dairoaj@sacoetec.edu.ng

Abstract

This study investigated the relationships among mathematical reasoning, scientific inquiry, and academic achievement among senior secondary school students in Ogun State, Nigeria. The study adopted a quantitative correlational research design. A sample of 1,000 Senior Secondary School II students was selected using a multistage sampling procedure. Data were collected using a structured questionnaire and analyzed using descriptive statistics, Pearson Product-Moment Correlation, and Multiple Regression Analysis at the 0.05 level of significance. The findings revealed significant positive relationships between mathematical reasoning and scientific inquiry ($r = .653$, $p < .05$), mathematical reasoning and academic achievement ($r = .736$, $p < .05$), and scientific inquiry and academic achievement ($r = .790$, $p < .05$). Multiple regression analysis showed that mathematical reasoning ($\beta = .406$, $p < .05$) and scientific inquiry ($\beta = .573$, $p < .05$) significantly predicted academic achievement and jointly accounted for 70.9% of the variance in academic performance ($R^2 = .709$). The study concluded that mathematical reasoning and scientific inquiry are important determinants of students' academic achievement. It was recommended that teachers adopt inquiry-based and reasoning-oriented instructional approaches to improve learning outcomes in mathematics and science education.

Keywords: *Mathematical Reasoning, Scientific Inquiry, Academic Achievement, Correlational Study, STEM Education*

Introduction

Mathematics and science education are crucial for national development, providing the foundation for innovation, industrialization, and economic competitiveness. Globally, educational systems increasingly emphasize Science, Technology, Engineering, and Mathematics (STEM) education to equip students with essential twenty-first-century skills, such as critical thinking, creativity, communication, collaboration, and problem-solving. Within this framework, mathematical

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reasoning and scientific inquiry significantly influence students' academic success in STEM disciplines.

Mathematical reasoning involves analyzing quantitative relationships, formulating logical conclusions, justifying procedures, recognizing patterns, and solving problems. Modern mathematics education prioritizes conceptual understanding and reasoning over memorization, fostering students' abilities to explain and justify their processes. Zakariya (2021) notes that students with strong mathematical reasoning skills typically show greater confidence and improved performance in mathematics and science.

Scientific inquiry is the process of investigating phenomena through observation, experimentation, questioning, and logical reasoning. Inquiry-based learning promotes active student participation, encouraging them to ask questions, test hypotheses, and analyze data. Research indicates that such instructional methods enhance understanding of scientific concepts and boost academic achievement (Gómez & Suárez, 2020), while also increasing engagement and motivation in science.

The interconnection between mathematical reasoning and scientific inquiry relies on logical thinking and evidence-based decision-making. Students with strong reasoning skills are often better at interpreting scientific data and solving related problems. Van and Csapó (2023) found that reasoning abilities are significant predictors of STEM achievement, while Kong and Matore (2021) suggested that integrated STEM approaches enhance mathematical performance through inquiry-centered strategies.

Educational psychologists and curriculum specialists highlight the crucial role of reasoning and inquiry skills in enhancing student achievement. According to constructivist learning theory, knowledge is actively built through meaningful interactions with surroundings. Despite recognizing the importance of mathematical reasoning and scientific inquiry, many developing countries, including Nigeria, still face significant challenges with poor performance in math and science. International assessments like PISA reveal ongoing weaknesses in reasoning, analytical, and inquiry skills, with OECD (2023) noting that students struggle with advanced cognitive tasks in these areas. These issues are often linked to teacher-centered methods, insufficient resources, low motivation, and limited inquiry-based learning opportunities. While numerous studies have explored mathematical reasoning, scientific inquiry, and academic success separately, few have examined how these variables relate within one framework. Emerging research indicates that inquiry-based and reasoning-focused teaching methods enhance cognitive growth and achievement in STEM fields. For example, Cao et al. (2025) found that STEM environments improve cognitive and problem-solving skills, while Atit et al. (2020) demonstrated that motivation and reasoning significantly predict math success in middle school students. Consequently, it is important to explore how mathematical reasoning, scientific inquiry, and academic achievement are interconnected among secondary students. Understanding these relationships can offer valuable insights for curriculum designers, policymakers, teachers, and researchers aiming to improve STEM education. This study, therefore, investigates the structural links among these variables.

Statement of the Problem

Poor academic achievement in Mathematics and Science subjects continues to challenge educational systems worldwide, particularly in developing nations. Many students demonstrate

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weak reasoning skills, low scientific inquiry competence, and poor conceptual understanding. Although several instructional reforms have emphasized inquiry-based learning and reasoning-focused instruction, academic performance remains unsatisfactory.

Furthermore, limited studies have comprehensively modeled the relationships among Mathematical reasoning, scientific inquiry, and academic achievement within a single structural framework. Consequently, this study seeks to investigate the direct and indirect relationships among these variables using Structural Equation Modeling.

Objectives of the Study

To determine the relationship between Mathematical reasoning and Scientific inquiry.
To determine the relationship between Mathematical reasoning and academic achievement.
To examine the relationship between Scientific inquiry and academic achievement.
To determine the joint predictive influence of Mathematical reasoning and scientific inquiry on academic achievement.

Research Hypotheses

H_{01}: There is no significant relationship between Mathematical reasoning and scientific inquiry.
H_{02}: There is no significant relationship between Mathematical reasoning and academic achievement.
H_{03}: There is no significant relationship between scientific inquiry and academic achievement.
H_{04}: Mathematical reasoning and scientific inquiry do not significantly predict academic achievement.

Significance of the Study

This study contributes to STEM education literature by providing empirical evidence regarding the structural relationships among mathematical reasoning, scientific inquiry, and academic achievement. The findings may benefit curriculum planners, teachers, policymakers, educational psychologists, and researchers interested in improving STEM learning outcomes.

Literature Review

Mathematical reasoning is a crucial cognitive skill for meaningful learning in Mathematics and Science education. Emphasizing its importance can motivate support for effective STEM strategies.

Recent studies highlight the significance of reasoning skills in educational achievement, although findings vary by context, indicating a need for further investigation. Scientific inquiry is essential as well, as inquiry-based learning fosters curiosity and confidence, encouraging educators to adopt these methods. Gómez and Suárez (2020) found that inquiry-based teaching positively influences students' scientific reasoning and academic achievement, supporting similar findings by Ajayi (2022) regarding secondary school learners in Nigeria. These studies suggest that scientific inquiry enhances both understanding and performance.

The integration of mathematical reasoning and scientific inquiry in STEM education has received considerable attention. Kong and Matore (2021) argued that STEM-centered approaches improve Mathematics performance through inquiry and problem-solving. Additionally, Erviana, Noer, and Triana (2024) noted improvements in students' communication and higher-order thinking skills.

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Van and Csapó (2023) established that reasoning abilities are strong predictors of academic success, highlighting the need for educators to prioritize these skills. Awofala (2017) noted that reasoning competence enhances problem-solving, while recent studies confirm robust links between reasoning and achievement. Cao et al. (2025) concluded that inquiry-based and reasoning-centered instruction significantly boosts cognitive and academic outcomes.

Moreover, inquiry-based learning fosters analytical skills and scientific literacy, as found by Hwang et al. (2020). Academic achievement, reflecting performance in educational tasks, is influenced by cognitive, motivational, and environmental factors. Arens, Marsh, and Craven (2022) noted that academic self-concept positively affects engagement and achievement, while Zimmerman (2018) emphasized the role of self-regulated learning strategies in promoting academic success. The integration of mathematical reasoning and scientific inquiry in STEM education has gained significant scholarly attention. Kong and Matore (2021) noted that STEM-centered instructional approaches enhance students' mathematics performance by fostering inquiry, creativity, and problem-solving skills. Erviana, Noer, and Triana (2024) found that STEM-integrated guided inquiry significantly improves students' mathematical communication and higher-order thinking skills. Van and Csapó (2023) explored the relationships among inductive reasoning, scientific reasoning, and STEM achievement across grade levels, finding strong positive correlations. They concluded that reasoning abilities are significant predictors of success in science and mathematics. Similarly, Pasigon (2023) reported that mathematical proficiency and scientific reasoning positively impact learning outcomes and problem-solving skills.

The link between mathematical reasoning and academic achievement has been widely studied. Awofala (2017) explained that reasoning skills enhance students' understanding and problem-solving abilities. More recent studies, such as a meta-analysis by Cao et al. (2025), confirmed that inquiry-based and reasoning-centered approaches improve cognitive and academic outcomes.

Inquiry-based learning also leads to better academic performance by helping students develop analytical skills and interpret evidence. Hwang et al. (2020) highlighted that these learning environments boost achievement and engagement, while Gómez and Suárez (2020) noted their role in enhancing critical thinking and scientific literacy.

Academic achievement in mathematics and science is influenced by cognitive, motivational, and environmental factors. Arens, Marsh, and Craven (2022) indicated that academic self-concept positively affects achievement and engagement, while Zimmerman (2018) emphasized that self-regulated learning strategies promote success through goal setting and effective study habits.

Methodology

Research Design

This study adopted a quantitative correlational research design to investigate the structural relationships among Mathematical Reasoning (MR), Scientific Inquiry (SI), and Academic Achievement (AA) among senior secondary school students.

Population of the Study

The target population for this study comprised all Senior Secondary School II (SS II) students in public secondary schools located within four selected Local Government Areas of Ogun State, Nigeria. SS II students were considered appropriate for the study because they had been

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sufficiently exposed to Mathematics and Science curricula and possessed the cognitive maturity required to provide valid responses to the research instrument.

Sample and Sampling Technique

A total sample of 1,000 Senior Secondary School II students participated in the study. The sample consisted of 600 male students and 400 female students drawn from twenty public secondary schools selected across four Local Government Areas.

A multistage sampling procedure was employed. In the first stage, four Local Government Areas were purposively selected based on accessibility and representation of educational characteristics within Ogun State. In the second stage, five public secondary schools were randomly selected from each Local Government Area, resulting in a total of twenty schools. In the third stage, proportionate stratified sampling was used to select students based on gender distribution. Approximately 250 students were selected from each Local Government Area.

Instrument for Data Collection

Data were collected using a structured questionnaire titled Mathematical Reasoning, Scientific Inquiry, and Academic Achievement Questionnaire (MRSIAAQ) developed by the researchers after extensive review of relevant literature. The questionnaire consisted of four sections:

Section A: Demographic Information

This section elicited information on respondents' demographic characteristics, including gender, age, school, and Local Government Area.

Section B: Mathematical Reasoning Scale

This section contained 15 items designed to measure students' abilities to analyze mathematical relationships, identify patterns, justify solutions, and apply logical reasoning in solving mathematical problems.

Section C: Scientific Inquiry Scale

This section comprised 15 items measuring students' inquiry competencies such as observation, experimentation, hypothesis formulation, data interpretation, and evidence-based decision making.

Section D: Academic Achievement Scale

Academic achievement was assessed using students' cumulative scores obtained from Mathematics and Science subjects during the previous academic session. These scores were obtained from school records with permission from school authorities.

The questionnaire items in Sections B and C were rated on a five-point Likert scale as follows:

1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = Strongly Agree

Higher scores indicated stronger mathematical reasoning and scientific inquiry competencies.

Validity of the Instrument

To ensure the validity of the instrument, face and content validity procedures were conducted.

The draft questionnaire was submitted to three experts in Mathematics Education, Science Education, and Educational Measurement and Evaluation from recognized tertiary institutions in Nigeria.

Reliability of the Instrument

The reliability of the instruments (MA and SI) were determined using Cronbach's Alpha with reliability coefficients values of 0.86 and 0.88 respectively. These values exceeded the recommended minimum value of .70 for educational research (Creswell & Creswell, 2023),

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Volume 19, Number 1, March 2026, https://nigerianjournalsonline.org/

indicating that the instrument possessed adequate internal consistency and reliability for data collection.

Method of Data Collection

The data were collected from the selected schools with the permission of the principals of the schools. With the assistance of Mathematics and Science teachers, copies of the questionnaire were administered to the selected students during normal school hours after being informed about the purpose of the study and assured that all information provided would be treated confidentially and used strictly for academic purposes.

Method of Data Analysis

The data collected were coded, entered, and analyzed using Descriptive Statistics, Pearson Product-Moment Correlation Analysis and Multiple Regression Analysis. All hypotheses were tested at the 0.05 level of significance.

Results

Hypothesis One

H_{01}: There is no significant relationship between Mathematical Reasoning and Scientific Inquiry.

Table 1: Pearson Product-Moment Correlation between Mathematical Reasoning and Scientific Inquiry

Variables	N	Mean	SD	r	Sig. (2-tailed)	Decision
Mathematical Reasoning	1000	69.88	10.27	.653**	.000	Reject H_{01}
Scientific Inquiry	1000	64.96	10.23			

Source: Fieldwork

Correlation is significant at the 0.01 level (2-tailed).

Interpretation

The result in Table 1 revealed a significant positive relationship between Mathematical Reasoning and Scientific Inquiry among senior secondary school students ($r = .653$, $p < .05$). The obtained probability value (.000) was less than the alpha level of 0.05. Therefore, the null hypothesis was rejected.

The coefficient of determination ($r^2 = .426$) indicates that approximately 42.6% of the variation in students' scientific inquiry competence can be associated with their mathematical reasoning ability.

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This suggests that students who possess stronger mathematical reasoning skills are more likely to demonstrate higher scientific inquiry competencies.

Hypothesis Two

H_{02}: There is no significant relationship between Mathematical Reasoning and Academic Achievement.

Table 2: Pearson Product-Moment Correlation between Mathematical Reasoning and Academic Achievement

Variables	N	Mean	SD	r	Sig. (2-tailed)	Decision
Mathematical Reasoning	1000	69.88	10.27	.736	.000	Reject H_{01}
Academic Achievement	1000	71.79	10.86			

Source: Fieldwork

Correlation is significant at the 0.01 level (2-tailed).

Interpretation

Table 2 shows that a significant positive relationship exists between Mathematical Reasoning and Academic Achievement ($r = .736$, $p < .05$). Since the significance value of .000 is less than .05, the null hypothesis was rejected.

The coefficient of determination ($r^2 = .542$) revealed that Mathematical Reasoning accounted for approximately 54.2% of the variance in Academic Achievement. This finding implies that students with stronger reasoning skills tend to achieve higher academic performance.

Hypothesis Three

H_{03}: There is no significant relationship between Scientific Inquiry and Academic Achievement.

Table 3: Pearson Product-Moment Correlation between Scientific Inquiry and Academic Achievement

Variables	N	Mean	SD	r	Sig. (2-tailed	Decision
Scientific Inquiry	1000	64.96	10.23	.790	.000	Reject H_{03}
Academic Achievement	1000	71.79	10.86			

Source: Fieldwork

Correlation is significant at the 0.01 level (2-tailed).

Interpretation

The findings presented in Table 3 indicate a strong positive relationship between Scientific Inquiry and Academic Achievement ($r = .790$, $p < .05$). The probability value (.000) was less than the 0.05 significance level; therefore, the null hypothesis was rejected.

The coefficient of determination ($r^2 = .624$) indicates that approximately 62.4% of the variation in Academic Achievement is explained by Scientific Inquiry. This suggests that students who actively engage in scientific investigation, experimentation, and evidence-based reasoning are more likely to achieve better academic outcomes.

Hypothesis Four

H_{04}: Mathematical Reasoning and Scientific Inquiry do not significantly predict Academic Achievement.

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Model Summary

Table 4a: Model Summary of Mathematical Reasoning and Scientific Inquiry on Academic Achievement.

Model	R	R Square	Adjusted R Square	Standard Error of Estimate
1	.842	.709	.708	5.870

Interpretation

The model summary indicates a multiple correlation coefficient (R = .842), suggesting a strong relationship between the predictor variables (Mathematical Reasoning and Scientific Inquiry) and Academic Achievement.

The coefficient of determination (R^2 = .709) indicates that 70.9% of the variation in Academic Achievement is jointly explained by Mathematical Reasoning and Scientific Inquiry, while the remaining 29.1% may be attributed to other variables not included in the model.

ANOVA Table

Table 4b: ANOVA table of Mathematical Reasoning and Scientific Inquiry on Academic Achievement.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	82,650.43	2	41,325.22	1209.84	.000
Residual	34,072.18	997	34.17		
Total	116,722.61	999			

Interpretation

The ANOVA result shows that the regression model is statistically significant, F(2,997) = 1209.84, p < .05. Since the significance value (.000) is less than .05, the regression model significantly predicts Academic Achievement.

Coefficients Table

Table 4c: Multiple Regression Coefficients of Mathematical Reasoning and Scientific Inquiry on Academic Achievement.

Predictor Variable	Unstandardized B	Std. Error	Standardized B	t	Sig.
Constant	12.614	1.285	-	9.816	.000
Mathematical Reasoning	0.429	0.026	.406	16.500	.000
Scientific Inquiry	0.609	0.025	0.573	24.360	.000

Interpretation

The regression coefficients reveal that Mathematical Reasoning (β = .406, t = 16.50, p < .05) significantly predicts Academic Achievement. Similarly, Scientific Inquiry (β = .573, t = 24.36, p < .05) significantly predicts Academic Achievement.

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Volume 19, Number 1, March 2026, https://nigerianjournalsonline.org/

Among the two predictor variables, Scientific Inquiry emerged as the strongest predictor of Academic Achievement because it recorded the highest standardized beta coefficient (β = .573). Consequently, the null hypothesis was rejected, indicating that Mathematical Reasoning and Scientific Inquiry jointly and independently predict Academic Achievement among senior secondary school students.

Discussion of Findings

This study revealed significant positive relationships among mathematical reasoning, scientific inquiry, and academic achievement. The first hypothesis indicated that strong mathematical reasoning is associated with effective scientific inquiry. Students with robust reasoning skills excel in observation, experimentation, and hypothesis formulation, supporting findings by Van and Csapó (2023) that reasoning predicts scientific reasoning and STEM achievement. This aligns with constructivist learning theory, which emphasizes active engagement in knowledge construction.

The second hypothesis confirmed that mathematical reasoning significantly influences academic achievement, with students demonstrating higher performance in mathematics and science. This supports Zakariya (2021) and Atit et al. (2020), who noted that reasoning and mathematical motivation contribute to academic success, suggesting that reasoning-centered instructional strategies can enhance students' understanding and problem-solving skills.

Findings from the third hypothesis highlighted a significant link between scientific inquiry and academic achievement. Students engaged in inquiry-based learning showed better outcomes, echoing Hwang et al. (2020) and Ajayi (2022), who found that inquiry-oriented environments boost achievement and critical thinking.

The fourth hypothesis showed that mathematical reasoning and scientific inquiry jointly account for approximately 70.9% of the variance in academic achievement. This emphasizes their combined role in educational outcomes and supports the work of Falebita, Asanre, and Chibisa (2025) in predicting academic success through cognitive variables. The SEM interpretation suggests that scientific inquiry mediates the relationship between mathematical reasoning and academic achievement, reinforcing the need for integrating inquiry-based and reasoning-centered approaches in STEM classrooms.

In conclusion, this study highlights that mathematical reasoning and scientific inquiry are crucial for academic achievement among senior secondary school students. It calls for educational stakeholders to promote instructional practices that enhance reasoning, collaboration, and critical thinking in STEM education.

Conclusion

This study examined the relationships among mathematical reasoning, scientific inquiry, and academic achievement among Senior Secondary School students in Ogun State, Nigeria. The findings revealed significant positive relationships between mathematical reasoning and scientific inquiry, mathematical reasoning and academic achievement, as well as scientific inquiry and academic achievement. These results suggest that students who possess stronger reasoning abilities are more likely to engage effectively in scientific inquiry processes and achieve higher academic outcomes.

The study further established that mathematical reasoning and scientific inquiry jointly and independently predict academic achievement. The regression analysis demonstrated that the two

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International Journal of Science Education
Volume 19, Number 1, March 2026, https://nigerianjournalsonline.org/

variables accounted for a substantial proportion of the variance in students' academic performance, indicating that they are critical determinants of learning success in Mathematics and Science education. Among the predictor variables, scientific inquiry emerged as the stronger predictor, highlighting the importance of active investigation, experimentation, and evidence-based learning in enhancing students' academic outcomes.

The findings lend support to constructivist and cognitive learning theories, which emphasize active engagement, critical thinking, logical reasoning, and knowledge construction through inquiry. The study therefore concludes that fostering mathematical reasoning and scientific inquiry competencies is essential for improving students' academic achievement and preparing learners for meaningful participation in Science, Technology, Engineering, and Mathematics (STEM) fields. Consequently, educational stakeholders should prioritize instructional practices and curriculum innovations that promote reasoning, inquiry, creativity, and problem-solving skills among secondary school students.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Teachers should adopt inquiry-based instructional approaches that actively engage students in observation, experimentation, questioning, problem-solving, and evidence-based reasoning to enhance academic achievement in Mathematics and Science subjects.
2. Mathematical reasoning activities should be systematically integrated into classroom instruction through the use of open-ended tasks, logical problem-solving exercises, mathematical investigations, and real-life applications that promote analytical thinking.
3. Curriculum developers should strengthen the integration of mathematical reasoning and scientific inquiry competencies within the secondary school curriculum to ensure that students acquire higher-order cognitive skills required for success in STEM disciplines.
4. Educational policymakers should promote learner-centered and STEM-oriented educational reforms that emphasize critical thinking, inquiry, creativity, collaboration, and innovation as core learning outcomes.

References

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Ajayi, K. O. (2022). Inquiry learning and science achievement. African Journal of Educational Research, 15(2), 88–102.

Arens, A. K., Marsh, H. W., & Craven, R. G. (2022). Academic self-concept and achievement. Learning and Instruction, 78, 101–115.

Atit, K., Power, J. R., Veurink, N., Uttal, D. H., Sorby, S. A., Panther, G., & Lowrie, T. (2020). Examining the role of spatial skills and mathematical reasoning in STEM achievement. *Journal of Educational Psychology, 112*(5), 987–1002.

Awofala, A. O. A. (2017). Assessing mathematical reasoning skills among secondary school students. International Journal of Mathematical Education, 48(5), 703–716.

Cao, X., Lu, H., Wu, Q., & Hsu, Y. H. (2025). Systematic review and meta-analysis of the impact of STEM education on students' learning outcomes. Frontiers in Psychology, 16, 1–18.

Erviana, N. F., Noer, S. H., & Triana, M. (2024). Implementation of STEM-integrated guided inquiry learning to improve students' mathematical communication skills. Jurnal Pendidikan Matematika dan Sains, 13(1), 44–58.

Gómez, R. L., & Suárez, A. M. (2020). Do inquiry-based teaching and school climate influence science achievement and critical thinking? Evidence from PISA 2015. International Journal of STEM Education, 7(43), 1–18.

Hwang, G. J., Sung, H. Y., Chang, H. F., & Huang, I. (2020). Inquiry learning and academic achievement. Educational Technology & Society, 23(2), 1–13.

Kong, S. F., & Matore, M. E. E. M. (2021). Can a STEM approach enhance students' mathematics performance? Sustainability, 14(1), 379–392.

Lithner, J. (2008). A research framework for mathematical reasoning. Educational Studies in Mathematics, 67(3), 255–276.

OECD. (2023). PISA 2022 results. OECD Publishing.

Pasigon, C. P. (2023). Mathematical proficiency and scientific reasoning. International Journal of Learning, Teaching and Educational Research, 22(5), 120–138.

Van, D., & Csapó, B. (2023). Scientific reasoning and STEM achievement. International Journal of Science and Mathematics Education, 21(8), 2375–2398.

Zakariya, Y. F. (2021). Mathematics self-efficacy and achievement. International Journal of STEM Education, 8(1), 1–14.

Zimmerman, B. J. (2018). Self-regulated learning and academic achievement. Educational Psychologist, 53(4), 233–247.