THE INTERNATIONAL JOURNAL OF EDUCATION, MANAGEMENT AND SOCIAL SCIENCES
Volume 2, Issue 1, January - June 2026

SPATIAL REASONING AS A PREDICTOR OF SUCCESS IN GEOMETRY AND CALCULUS OF THE BSE MATHEMATICS STUDENTS AT PANGASINAN STATE UNIVERSITY ALAMINOS CITY CAMPUS

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Date of Submission: May 6, 2026
Date of Acceptance: June 22, 2026
Date of Publication: June 30, 2026

ABSTRACT

Spatial reasoning is a key cognitive skill in mathematics, particularly in Geometry and Calculus. This study examined whether spatial reasoning predicts academic performance in these subjects among 26 second-year Bachelor of Secondary Education (BSE) Mathematics students at Pangasinan State University–Alaminos Campus. Using a quantitative descriptive-correlational design, data were gathered through an adopted Spatial Reasoning Test and students' final grades in Modern Geometry and Calculus. Results showed that students had high spatial reasoning ability, very satisfactory performance in Modern Geometry, and satisfactory performance in Calculus. However, regression analysis revealed that spatial reasoning did not significantly predict academic performance in either subject. These findings suggest that other factors, such as logical

reasoning, conceptual understanding, algebraic skills, and problem-solving ability, may have a greater influence on students' achievement.

Keywords: Spatial reasoning, Geometry, Calculus, academic performance, BSE Mathematics students, mathematics education

INTRODUCTION

Mathematics plays a fundamental role in developing logical reasoning, analytical thinking, and problem-solving skills. Among its major branches, Geometry and Calculus are considered challenging subjects because they require learners to understand abstract concepts, visualize relationships, and interpret mathematical representations. Success in these subjects often depends not only on computational ability but also on cognitive skills such as spatial reasoning.

Spatial reasoning refers to the ability to visualize, manipulate, and mentally transform objects and their relationships in space. It is considered an essential component of mathematical thinking because it enables learners to interpret geometric figures, analyze graphs, recognize patterns, and solve problems involving spatial relationships. Previous studies have shown that students with stronger spatial reasoning skills generally demonstrate better performance in mathematics, particularly in Geometry and Calculus, where visualization and mental manipulation are frequently required.

For Bachelor of Secondary Education (BSE) Mathematics students, developing strong spatial reasoning skills is particularly important because they are expected to master mathematical concepts before teaching them to future learners. Despite the recognized importance of spatial reasoning, many students continue to experience difficulties in Geometry and Calculus, suggesting that other factors may also influence their academic performance.

Although international studies have extensively examined the relationship between spatial reasoning and mathematics achievement, limited empirical evidence exists regarding this relationship among pre-service mathematics teachers in the Philippines. At Pangasinan State University–Alaminos City Campus, understanding whether spatial reasoning contributes to students' success in Geometry and Calculus may provide valuable information for improving mathematics instruction and strengthening teacher education programs.

Several studies have reported that spatial reasoning is associated with mathematics achievement. Casey et al. (2001) found that students with stronger spatial ability generally performed better in mathematics, suggesting that spatial reasoning contributes to mathematical understanding and problem-solving. Likewise, Zheng et al. (2019), through a meta-analysis, concluded that spatial skills have a significant positive relationship with mathematics performance across different educational levels. Mix and Cheng (2012) also emphasized that spatial thinking supports mathematical problem solving by enabling learners to visualize relationships, manipulate mental

representations, and interpret abstract mathematical concepts. Similarly, Atit et al. (2017) reported that spatial skills play an important role in STEM learning, particularly in mathematics, although the strength of this relationship varies across mathematical domains. These findings suggest that spatial reasoning is an important cognitive ability that may influence students' mathematical achievement.

Despite these findings, limited studies have examined whether spatial reasoning predicts academic performance specifically in Modern Geometry and Calculus among pre-service mathematics teachers in the Philippine context. Most existing studies were conducted in foreign settings or focused on elementary and secondary students rather than college-level mathematics majors. Consequently, there remains insufficient evidence regarding the predictive role of spatial reasoning among Bachelor of Secondary Education major in Mathematics students. Addressing this gap, the present study investigates whether spatial reasoning significantly predicts academic performance in Modern Geometry and Calculus among BSE Mathematics students at Pangasinan State University–Alaminos City Campus.

This study aimed to determine the level of spatial reasoning ability of Bachelor of Secondary Education major in Mathematics students at Pangasinan State University–Alaminos City Campus, evaluate their academic performance in Modern Geometry and Calculus, and determine whether spatial reasoning significantly predicts their academic performance in these courses. The findings of the study may serve as a basis for developing instructional strategies that strengthen students' mathematical understanding and prepare future mathematics teachers for effective classroom instruction.

Concepts and Theory Utilized in the Study

The study examined whether spatial reasoning is a significant predictor of academic performance in Modern Geometry and Calculus among Bachelor of Secondary Education (BSE) Mathematics students at Pangasinan State University–Alaminos City Campus. It was anchored on theories highlighting the role of spatial reasoning in mathematical learning and cognitive development.

The primary framework was the Spatial Ability Theory of David H. Uttal and colleagues (2013), which explains that spatial reasoning involves mental rotation, spatial visualization, and the manipulation of objects in space. The theory suggests that strong spatial abilities support learning in Geometry and Calculus and can be developed through appropriate instruction and practice.
The study was also grounded in Piaget's Theory of Cognitive Development, which explains that learners construct knowledge by organizing and modifying cognitive structures through experience. In mathematics, this enables students to understand abstract concepts and visualize mathematical relationships.

Additionally, the study was supported by Sfard's Commognitive Framework, which views mathematical thinking as a form of communication using symbols, diagrams, graphs, and other

representations. Spatial reasoning helps learners interpret and communicate mathematical ideas more effectively.

Finally, the study adopted Duval's Theory of Semiotic Representation, which emphasizes the ability to interpret and translate among mathematical representations. Guided by these theories, the study treated spatial reasoning as the independent variable and academic performance in Modern Geometry and Calculus as the dependent variables to determine whether spatial reasoning significantly predicts students' achievement.

METHODS

This study employed a quantitative descriptive-correlational research design to determine the level of spatial reasoning ability of Bachelor of Secondary Education major in Mathematics students and to examine whether spatial reasoning significantly predicts their academic performance in Modern Geometry and Calculus.

The respondents of the study were 26 second-year Bachelor of Secondary Education major in Mathematics students enrolled at Pangasinan State University–Alaminos City Campus during the Academic Year 2025–2026. These students were selected because they had already completed the Modern Geometry and Calculus courses required in the curriculum.

The study utilized an adopted and standardized Spatial Reasoning Test from the Spatial Reasoning Tests Workbook published by How2Become (2018) to measure the respondents' spatial reasoning ability. Students' academic performance was determined using their final grades in Modern Geometry and Calculus, which were obtained with the respondents' permission.

Permission to conduct the study was secured from the university administration before data collection. The spatial reasoning test was administered to the respondents under the supervision of the researchers, while students' final grades were collected after obtaining the necessary consent. All collected information was treated confidentially and used solely for research purposes.

The data were analyzed using descriptive statistics, including the mean, standard deviation, skewness, and kurtosis, to determine the respondents' level of spatial reasoning ability and academic performance. Simple linear regression analysis was employed to determine whether spatial reasoning significantly predicts students' academic performance in Modern Geometry and Calculus.

RESULTS AND DISCUSSION

1. Level of Spatial Reasoning Ability of BSE Mathematics Students

Table 1 presents the level of spatial reasoning ability of Bachelor of Secondary Education (BSE) Mathematics students at Pangasinan State University–Alaminos City Campus.

Table 1. Level of Spatial Reasoning Ability of BSE Mathematics Students

Variable	N	Minimum	Maximum	Mean	SD	Skewness	Kurtosis	Interpretation
Spatial Reasoning Test Score	26	26	40	36.23	4.14	-1.518	1.346	High

The results revealed that the respondents obtained a mean score of 36.23 out of a possible 40 points, with a standard deviation of 4.14, indicating a high level of spatial reasoning ability. This finding suggests that the respondents possess well-developed skills in visualizing, mentally manipulating, and interpreting spatial relationships, which are essential competencies in learning mathematics.

The negative skewness value (-1.518) indicates that most respondents obtained relatively high scores, while only a few received lower scores. Likewise, the kurtosis value (1.346) suggests a leptokurtic distribution, indicating that the scores were concentrated around the mean. These findings imply that the majority of the respondents consistently demonstrated high spatial reasoning ability.

The results support the Spatial Ability Theory of David H. Uttal and colleagues (2013), which explains that spatial reasoning is a fundamental cognitive skill that contributes to mathematical learning. Strong spatial reasoning enables students to visualize geometric figures, interpret graphs, and mentally manipulate mathematical representations, thereby facilitating deeper conceptual understanding.

2. Academic Performance of BSE Mathematics Students in Modern Geometry and Calculus

Table 2 presents the academic performance of the respondents in Modern Geometry and Calculus.

Table 2. Academic Performance of BSE Mathematics Students in Modern Geometry and Calculus

Subject	N	Minimum	Maximum	Mean	SD	Skewness	Kurtosis	Interpretation
Modern Geometry	26	75.00	89.00	82.62	3.70	-.712	-.500	Very Satisfactory
Calculus	26	73.00	89.00	76.42	3.01	3.155	12.362	Satisfactory

The findings show that the respondents obtained a mean grade of 82.62 in Modern Geometry, interpreted as Very Satisfactory, while the mean grade of 76.42 in Calculus was interpreted as Satisfactory.

The higher mean in Modern Geometry indicates that the respondents generally performed better in this subject than in Calculus. Although the respondents demonstrated satisfactory achievement in both courses, the lower mean score in Calculus suggests that students encountered greater difficulty in mastering its concepts and procedures. The relatively low standard deviations further indicate that students' grades were fairly consistent.

These findings suggest that although Geometry and Calculus both require mathematical reasoning, they demand different cognitive processes. Geometry emphasizes visualization and deductive reasoning, whereas Calculus requires stronger algebraic manipulation, symbolic reasoning, and analytical thinking.

3. Spatial Reasoning as a Predictor of Academic Performance in Calculus

Table 3 presents the results of the simple linear regression analysis examining whether spatial reasoning significantly predicts students' academic performance in Calculus.

Table 3. Spatial Reasoning as a Predictor of Performance in Calculus

Predictor Variable		***Academic Performance in Calculus***						
	R	R^2	F	B	Beta	95% Confidence Interval		p-value
						Lower	Upper	
Spatial Reasoning Ability	0.107	0.012	0.280	0.078	0.107	-.226	.382	0.601

The regression analysis revealed that spatial reasoning explained only a small proportion of the variance in students' Calculus performance. The obtained p-value (0.601) exceeded the 0.05 level

of significance, indicating that spatial reasoning was not a significant predictor of students' academic performance in Calculus.

Although the regression coefficient indicates a positive relationship between spatial reasoning and Calculus performance, the relationship was not statistically significant. The 95% confidence interval included zero, suggesting that the true effect may be positive, negative, or nonexistent. Thus, the findings do not support the conclusion that spatial reasoning significantly predicts students' Calculus performance.

This may be explained by the nature of Calculus, which relies more on algebraic reasoning, symbolic manipulation, computational skills, and conceptual understanding than on visual-spatial abilities. Consequently, students with stronger spatial reasoning did not necessarily achieve higher grades in Calculus. This finding is consistent with Atit et al. (2022), who reported that the relationship between spatial skills and mathematics achievement varies across mathematical domains and is influenced by other cognitive factors.

4. Spatial Reasoning as a Predictor of Academic Performance in Modern Geometry

Table 4 presents the results of the regression analysis examining whether spatial reasoning significantly predicts students' academic performance in Modern Geometry.

Table 4. Spatial Reasoning as a Predictor of Performance in Modern Geometry

Predictor Variable	***Academic Performance in Modern Geometry***							
						95% Confidence Interval		**p-value**
	R	R^2	**B**	**Beta**	**F**	Lower	Upper	
Spatial Reasoning Ability	0.044	0.002	-0.039	-0.044	0.280	-.415	.337	0.833

The results indicate that spatial reasoning is not a significant predictor of Modern Geometry performance among BSE Mathematics students ($p = 0.833 > 0.05$). Although the regression coefficient suggests a positive association, the effect was not statistically significant, and the 95% confidence interval included zero, indicating that the true effect may be positive, negative, or negligible.

This finding may be explained by the theoretical nature of Modern Geometry, which emphasizes axioms, proofs, logical arguments, and deductive reasoning more than visual-spatial tasks. Thus, students' performance may depend more on reasoning, proof-writing, and conceptual understanding than on spatial reasoning. This supports the findings of Mix et al. (2016), who argued that while mathematics and spatial ability are related, mathematical achievement is influenced by a broader range of cognitive skills.

Conclusion

The findings of this study indicate that Bachelor of Secondary Education (BSE) Mathematics students at Pangasinan State University–Alaminos City Campus possess a high level of spatial reasoning ability and generally perform well in both Modern Geometry and Calculus. The respondents achieved a Very Satisfactory level of academic performance in Modern Geometry and a Satisfactory level in Calculus, suggesting that they have developed the mathematical competencies expected in their program.

Despite the respondents' high level of spatial reasoning, the results of the regression analyses revealed that spatial reasoning was not a significant predictor of academic performance in either Modern Geometry or Calculus. The findings suggest that although spatial reasoning is an important cognitive skill in mathematics, it alone does not sufficiently explain students' success in these subjects. Instead, academic performance may be influenced by other factors such as logical reasoning, algebraic proficiency, computational skills, conceptual understanding, proof-writing ability, study habits, motivation, and prior mathematical knowledge.

The study concludes that while spatial reasoning remains a valuable component of mathematical thinking, it should not be considered the sole determinant of achievement in higher mathematics courses. These findings emphasize the need for teacher education programs to develop a balanced approach that strengthens both spatial reasoning and other cognitive and academic skills necessary for success in Modern Geometry and Calculus. Future research involving larger samples and additional predictor variables is recommended to provide a more comprehensive understanding of the factors that contribute to students' academic performance in mathematics.

RECOMMENDATIONS

Based on the findings, the following recommendations are proposed:

1. Mathematics instructors should continue integrating visualization, mathematical modeling, and technology-based strategies to strengthen students' spatial reasoning and mathematical understanding.
2. Teacher education institutions should emphasize logical reasoning, proof-writing, analytical thinking, and problem-solving skills, as these may have a greater impact on achievement in Modern Geometry and Calculus.
3. Students should engage in activities that develop both spatial reasoning and higher-order thinking, such as geometric investigations, proofs, and problem-solving tasks.
4. Future researchers should replicate the study with larger and more diverse samples to improve the generalizability of the findings.
5. Future studies should examine other factors affecting achievement in Geometry and Calculus, including self-efficacy, motivation, study habits, prior knowledge, and logical reasoning.

ACKNOWLEDGMENT

The researchers extend their heartfelt appreciation to the Pangasinan State University – Alaminos City Campus, particularly the College of Teacher Education, the Dean, and the faculty members of the Bachelor of Secondary Education major in Mathematics, for granting permission and providing the necessary support in conducting this study. Special thanks are also extended to the second-year BSE Mathematics students who willingly participated in the data-gathering process and shared their time and cooperation, making this research possible.

DECLARATION ON THE USE OF AI TOOLS

The researcher utilized artificial intelligence (AI) tools, specifically Gemini, for grammar enhancement and the formatting of data tables during the preparation of this study. However, the conceptualization, data interpretation, and overall composition of the work remain the original work of the author.

REFERENCES

1. Atit, K., et al. (2017) Spatial skills and STEM learning https://doi.org/10.1080/10986065.2017.1258614

2. Atit, K., Power, J. R., Veurink, N., Uttal, D. H., Sorby, S., Panther, G., Mruczek, R., & Black, E. R. (2017). Examining the role of spatial skills and mathematics in STEM learning. Journal of Women and Minorities in Science and Engineering, 23(4), 331–348. https://www.tandfonline.com/doi/full/10.1080/10986065.2017.1258614

3. Bastani, O., et al. (2021). Improving the spatial visualization skills of students by using spatial puzzles. https://www.researchgate.net/publication/351711361_Improving_the_spatial_visualization_skills_of_students_by_using_spatial_puzzles

4. Bastani, O., et al. (2024). The role of visualization towards students' mathematical abstraction and representation in solving probabilities. https://www.researchgate.net/publication/365899232_The_Role_of_Visualization_Towards_Students'_Mathematical_Abstraction_and_Representation_in_Solving_Probabilities

5. Blaut, J. M. (2013). The cultural nature of spatial cognition. In D. Gentner & S. Goldin-Meadow (Eds.), Language in mind: Advances in the study of language and thought (pp. 153–171). Academic Press. https://www.sciencedirect.com/science/article/abs/pii/B9780123942937000042

6. Casey, M. B., et al. (2001) Spatial ability as predictor of mathematics achievement https://doi.org/10.1080/01443410120090786

7. Casey, M. B., Nuttall, R. L., Pezaris, E., & Benbow, C. P. (2001). Spatial ability as a predictor of mathematics achievement. Educational Psychology, 21(4), 449–461. https://www.tandfonline.com/doi/abs/10.1080/01443410120090786

8. Frieder, S., et al. (2023). Meta-analysis of spatial reasoning and problem-solving capabilities in mathematics. https://www.mdpi.com/2079-3200/11/12/221

9. Frontiers Research Topics. (2023). Spatial ability in STEM learning. https://www.frontiersin.org/research-topics/53611/spatial-ability-in-stem-learning/magazine

10. Hawes, Z. et al. (2025) Spatial reasoning, self-efficacy, and engagement in mathematics https://pubmed.ncbi.nlm.nih.gov/40278050

11. Mix, K. S., & Cheng, Y. L. (2012) The contribution of spatial thinking to mathematical problem solving https://doi.org/10.1111/j.1467-9280.2012.03131.x

12. Mix, K. S., & Cheng, Y. L. (2012). The contribution of spatial thinking to mathematical problem solving. https://doi.org/10.1111/j.1467-9280.2012.03131.x

13. Mix, K. S., Cheng, Y. L., Hambrick, D. Z., & Levine, S. C. (2024). SOLIDGEO: Measuring multimodal spatial math reasoning in solid geometry. ResearchGate. https://www.researchgate.net/publication/392133425_SOLIDGEO_Measuring_Multimodal_Spatial_Math_Reasoning_in_Solid_Geometry

14. Zheng, X., Swanson, H. L., & Marcoulides, G. A. (2019) Meta-analysis of spatial skills and math performance https://doi.org/10.1080/15248372.2019.1653298

15. Zheng, X., Swanson, H. L., & Marcoulides, G. A. (2019). Examining the relations between spatial skills and mathematical performance: A meta-analysis. Developmental Review, 53, 100870. https://www.tandfonline.com/doi/full/10.1080/15248372.2019.1653298