

THE EFFECT OF LEARNING STYLES ON JUNIOR HIGH SCHOOL STUDENTS' SPATIAL REASONING IN THREE-DIMENSIONAL GEOMETRY

Fatus Atho'ul Malik

Prodi Tadris Matematika, Institut Alif Muhammad Imam Syafi'I, Indonesia

fatusathoulmalik@gmail.com

Riwayat Artikel:

Diajukan: Desember 2025

Diterima: Desember 2025

Diterbitkan: Januari 2026

Abstract

Spatial reasoning ability is crucial in mathematics learning, particularly in three-dimensional geometry. However, its development faces various obstacles, including limited instructional media and teaching approaches that do not accommodate students' learning style diversity. This study aimed to examine the effect of learning styles (visual, auditory, kinesthetic) on junior high school students' spatial reasoning abilities. A mixed-methods sequential explanatory design was employed, involving 30 ninth-grade students from SMP Bustanul Hikmah Lamongan. Quantitative data were collected through learning style questionnaires and spatial reasoning tests covering spatial perception, spatial visualization, and spatial rotation. Qualitative data were obtained through observations and in-depth interviews with three selected subjects representing each learning style. Quantitative analysis using One-Way ANOVA revealed significant differences in spatial reasoning abilities based on learning styles ($F = 18.049, p < 0.001$). Kinesthetic students demonstrated the highest average scores, followed by visual and auditory students. Post Hoc Bonferroni tests indicated that both kinesthetic and visual learning styles were significantly more effective than auditory styles. Qualitative findings revealed distinct characteristics: auditory students relied on internal verbalization and struggled with complex visualization, visual students created detailed visual representations but were limited in dynamic transformations, kinesthetic students integrated physical gesture simulation with adaptive strategy flexibility. These findings suggest that geometry instruction should accommodate learning style diversity through varied instructional modalities, appropriate scaffolding, and compensatory strategy training. The use of technology such as virtual manipulatives, 3D animations, and augmented reality is recommended to optimize spatial reasoning development across all learning styles.

Keywords: learning styles, spatial reasoning, three-dimensional geometry, mathematics learning

Abstrak

Kemampuan penalaran spasial merupakan kompetensi penting dalam pembelajaran matematika, khususnya geometri bangun ruang. Namun, pengembangannya menghadapi berbagai hambatan, termasuk keterbatasan media pembelajaran dan pendekatan pengajaran yang belum mengakomodasi keberagaman gaya belajar siswa. Penelitian ini bertujuan mengkaji pengaruh gaya belajar (visual, auditori, kinestetik) terhadap kemampuan penalaran spasial siswa SMP. Penelitian menggunakan pendekatan mixed methods dengan desain sequential explanatory, melibatkan 30 siswa kelas IX SMP Bustanul Hikmah Lamongan. Data kuantitatif dikumpulkan melalui angket gaya belajar dan tes penalaran spasial yang mencakup spatial perception, spatial visualization, dan spatial rotation. Data kualitatif diperoleh melalui observasi dan wawancara mendalam dengan tiga subjek terpilih yang mewakili masing-masing gaya belajar. Analisis

kuantitatif menggunakan uji *One-Way ANOVA* menunjukkan perbedaan signifikan kemampuan penalaran spasial berdasarkan gaya belajar ($F = 18,049, p < 0,001$). Siswa kinestetik memiliki rata-rata skor tertinggi, diikuti visual dan auditori. Uji *Post Hoc Bonferroni* menunjukkan gaya belajar kinestetik dan visual sama-sama lebih efektif dibandingkan auditori. Temuan kualitatif mengungkapkan karakteristik unik: siswa auditori mengandalkan verbalisasi internal dan kesulitan pada visualisasi kompleks, siswa visual membuat representasi visual detail namun terbatas pada transformasi dinamis, siswa kinestetik mengintegrasikan simulasi gestur fisik dengan fleksibilitas strategi adaptif. Temuan ini menyarankan pembelajaran geometri perlu mengakomodasi keberagaman gaya belajar melalui berbagai modalitas pembelajaran, *scaffolding* yang sesuai, dan pelatihan strategi kompensasi. Penggunaan teknologi seperti *manipulatif virtual*, animasi 3D, dan *augmented reality* direkomendasikan untuk mengoptimalkan pengembangan penalaran spasial pada semua gaya belajar.

Kata kunci: gaya belajar, penalaran spasial, geometri bangun ruang, pembelajaran matematik

INTRODUCTION

Spatial reasoning ability is one of the essential competencies in mathematics learning, particularly in three-dimensional geometry (Xie et al., 2020). This ability encompasses visualization, spatial orientation, and understanding the relationships among objects in three-dimensional space (Riyanto et al., 2024). Spatial reasoning is consistently correlated with student performance in STEM (Science, Technology, Engineering, and Mathematics) subjects (Lowrie & Diezmann, 2007). More than three decades of research has shown that spatial reasoning and mathematics are strongly correlated (Lowrie et al., 2019).

Despite its importance, the development of spatial reasoning still faces various challenges. Primary obstacles include limited three-dimensional learning media Fitriyah & Putri (2024), poor curriculum integration, and the dominance of abstract learning approaches (Lokollo et al., 2024). Ayuningrum et al. (2019) revealed that many students experience difficulties in understanding and solving three-dimensional geometry problems, particularly in visualizing three-dimensional shapes and performing mental transformations of geometric objects.

One factor that influences spatial reasoning ability is learning style (Maftuh & Ni'mah, 2023). Learning style represents the different ways individuals receive and process information (Silaban et al., 2024). Differences in learning styles, visual, auditory, or kinesthetic, can significantly impact the understanding of three-dimensional geometry concepts (Basiran et al., 2021) and the development of spatial reasoning abilities (Oktavianto, 2022). Several studies have revealed that alignment between students' learning styles and teaching methods can enhance conceptual understanding (Awado et al., 2024).

In reality, three-dimensional geometry instruction at the junior high school level remains conventional and has not accommodated the diversity of student learning styles. Septian et al. (2022) revealed that most teachers still apply lecture methods and textbook-

based learning without considering different learning preferences. Teaching approaches that tend to be uniform can cause some students to struggle in optimizing their spatial reasoning abilities (Febrianti et al., 2024).

Previous research has examined the relationship between learning styles and spatial reasoning, but most have been quantitative in nature or focused only on one particular learning style. Danişman & Erginer (2017) found that visual learning preferences play an important role in mathematical reasoning and spatial ability. Maftuh & Alisya (2023) showed that students with visual learning styles have better spatial abilities, but the study only focused on visual learning styles. Comprehensive research integrating quantitative and qualitative analysis for all types of learning styles remains limited.

This study aims to examine in depth the effect of learning styles on junior high school students' spatial reasoning using a mixed-methods approach. The quantitative approach is used to identify significant differences and determine the most effective learning style, while the qualitative approach explores the characteristics and patterns of learning styles in developing spatial reasoning abilities. The integration of both approaches provides a comprehensive understanding of the cognitive mechanisms underlying the relationship between learning styles and spatial reasoning, as well as practical implications for developing adaptive learning strategies.

RESEARCH METHODS

Research Design

This study employed a mixed-methods approach with a sequential explanatory design (Creswell, John W Clark, 2017). This design was chosen because it allows researchers to collect and analyze quantitative data first, then use qualitative data to explain and deepen the quantitative results (Ivankova et al., 2006).

Participants

The study was conducted at SMP Bustanul Hikmah Lamongan in the first semester of the 2025/2026 academic year. The research population consisted of 30 ninth-grade students. The selection of ninth grade was based on the consideration that students at this level have learned three-dimensional geometry material and possess sufficient cognitive maturity.

For the qualitative phase, three subjects were selected using purposive sampling technique with the following criteria: (1) representing each learning style category, (2) having good communication skills based on teacher recommendations, and (3) willing to participate in in-depth interviews.

Research Instruments

Quantitative Instruments

Learning Style Questionnaire. Adapted from Sugianto (2021) instrument, consisting of 14 statement items with 3 answer choices representing visual, auditory, and kinesthetic learning styles. Content validity was confirmed by two mathematics education experts.

Spatial Reasoning Test. Developed based on indicators of spatial perception, spatial visualization, and spatial rotation (Ramful et al., 2017). The instrument consists of 3 problems with scoring rubrics validated by mathematics education lecturers. The maximum score is 100, with categories: high, medium, and low.

Qualitative Instruments

Observation Guide. Includes aspects of student interaction with materials, learning strategies, media use, and responses to teaching methods.

Interview Guide. Semi-structured interviews include questions about thinking processes, visualization strategies, learning preferences, and difficulties encountered.

Data Collection Procedures

Quantitative Phase. (1) Administration of learning style questionnaires to all students, (2) Observation of three-dimensional geometry learning, (3) Implementation of spatial reasoning tests, (4) Analysis of results using SPSS.

Qualitative Phase. (1) Selection of 3 subjects based on learning style categories, (2) In-depth interviews, (3) Transcription and analysis of interview data, (4) Triangulation of data from various sources.

Data Analysis

Quantitative Analysis. Using descriptive and inferential statistics with IBM SPSS version 25. Prerequisite tests include normality test (Shapiro-Wilk) and homogeneity test (Levene). Hypothesis testing uses One-Way ANOVA to test differences and effects of learning styles on spatial reasoning, followed by Post Hoc Bonferroni to identify significantly different groups.

Qualitative Analysis. Following the stages of Milles & Huberman (1994): (1) examining data, (2) reducing data, (3) validating data through triangulation, (4) presenting data, (5) drawing conclusions. Triangulation was conducted by comparing data from questionnaires, observations, tests, and interviews.

RESULTS AND DISCUSSION

Distribution of Learning Styles and Spatial Reasoning Levels

The questionnaire analysis results showed the distribution of learning styles as presented in Table 1.

Table 1. Distribution of Students' Learning Styles

| Learning Style | Frequency | Percentage (%) |
|----------------|-----------|----------------|
| Auditory | 8 | 26,7 |
| Kinesthetic | 9 | 30 |
| Visual | 13 | 43,3 |
| Total | 30 | 100 |

As shown in Table 1, visual 43.3% (13 students), kinesthetic 30% (9 students), and auditory 26.7% (8 students). The dominance of visual learning style is consistent with Danişman & Erginer (2017) research, which found that visual learning style plays an important role in mathematics learning involving spatial representation.

The distribution of spatial reasoning levels is presented in Table 2.

Table 2. Distribution of Students' Spatial Reasoning Levels

| Spatial Reasoning Level | Frequency | Presentage (%) |
|-------------------------|-----------|----------------|
| Low | 7 | 23,3 |
| Medium | 18 | 60 |
| High | 5 | 16,7 |
| Total | 30 | 100 |

Table 2 shows that 60% of students were in the medium category, 23.3% in the low category, and only 16.7% in the high category. The low percentage of students with high spatial reasoning is an important concern given that this ability is strongly correlated with achievement in STEM fields (Xie et al., 2020).

Differences and Effects of Learning Styles on Spatial Reasoning

Prerequisite Test Results

Before conducting hypothesis testing, prerequisite tests were performed. The normality test results are presented in Table 3.

Table 3. Normality Test Results

| Variable | Interpretation | Sig. |
|-------------------|----------------|-------|
| Spatial Reasoning | Normal (>0,05) | 0,083 |

Table 3 shows that the significance value of 0.083 ($p > 0.05$) indicates that the spatial reasoning data are normally distributed. The homogeneity test results are presented in Table 4.

Table 4. Homogeneity of Variance Test Results

| Variable | Levens Statistic | df1 | df2 | Sig. | Interpretation |
|----------|------------------|-----|-----|------|----------------|
|----------|------------------|-----|-----|------|----------------|

| | | | | | |
|-------------------|-------|---|----|--------|-----------------------|
| Spatial Reasoning | 0,252 | 2 | 27 | 0,0779 | Variances homogeneous |
|-------------------|-------|---|----|--------|-----------------------|

Table 4 shows that the significance value of 0.779 ($p > 0.05$) indicates homogeneous variance across learning style groups, allowing the ANOVA analysis to proceed.

Hypothesis Testing

The One-Way ANOVA test results are presented in Table 5.

Table 5. One-Way ANOVA Results

| | Sum of Square | df | Mean Square | F | Sig. |
|----------------|---------------|----|-------------|--------|-------|
| Between Groups | 1856.269 | 2 | 928.135 | 18.049 | 0.000 |
| Within Groups | 1388.431 | 27 | 51.423 | | |
| Total | 3244.700 | 29 | | | |

Table 5 shows significant differences in spatial reasoning abilities based on learning styles ($F = 18.049, p < 0.001$). This confirms that learning style significantly affects students' spatial reasoning abilities in three-dimensional geometry learning.

To identify which learning styles differ significantly, Post Hoc Bonferroni test was conducted. The results are presented in Table 6.

Table 6. Post Hoc Bonferroni Test Results

| | Mean Differen | Sig. |
|------------------------|---------------|-------|
| Auditory – Kinesthetic | -19.653 | 0,000 |
| Kinesthetic – Visual | 3.778 | 0,705 |
| Visual – Auditory | 15.875 | 0,000 |

Table 6 shows that: (1) kinesthetic learning style was significantly higher than auditory, (2) visual learning style was significantly higher than auditory, (3) there was no significant difference between kinesthetic and visual. These findings indicate that both kinesthetic and visual learning styles are equally effective and significantly more effective than auditory style.

To provide a more detailed picture of the distribution of spatial reasoning levels across learning style categories, cross-tabulation analysis was conducted. The results are presented in Table 7.

Table 7. Cross-tabulation of Learning Styles and Spatial Reasoning Levels

| Learning Style | Spatial Reasoning Level | | | | | | Total | |
|----------------|-------------------------|------|--------|------|------|------|-------|-----|
| | Low | | Medium | | High | | | |
| | N | % | N | % | N | % | N | % |
| Auditory | 7 | 87,5 | 1 | 12,7 | 0 | 0 | 8 | 100 |
| Kinesthetic | 0 | 0 | 6 | 66,7 | 3 | 33,3 | 9 | 100 |
| Visual | 0 | 0 | 11 | 84,6 | 2 | 15,4 | 13 | 100 |
| Total | 7 | 23,3 | 18 | 60 | 5 | 16,7 | 30 | 100 |

Table 7 reveals important patterns in the relationship between learning styles and spatial reasoning levels. Kinesthetic students had the highest average scores, followed by visual and auditory students. Cross-tabulation revealed that 33.3% of kinesthetic students reached the high category, while 87.5% of auditory students were in the low category.

These findings confirm that learning style significantly affects spatial reasoning, consistent with information processing theory which states that the way individuals receive and process spatial information is strongly influenced by sensory modality (Mahadi et al., 2022). Kinesthetic students who use movement-based representations have advantages in tasks involving mental manipulation of three-dimensional objects.

The Most Effective Learning Style

The Post Hoc Bonferroni test was conducted to examine pairwise comparisons between learning styles. The results showed that kinesthetic learning style was significantly higher than auditory learning style in promoting spatial ability. Similarly, visual learning style demonstrated significantly better outcomes compared to auditory learning style. Interestingly, there was no significant difference between kinesthetic and visual learning styles, indicating that both modalities produced comparable effects on students' spatial reasoning performance.

The superiority of kinesthetic learning style can be explained through the formation of strong mental representations from sensorimotor experiences (Gómez-Tone et al., 2021). Qualitative analysis revealed that kinesthetic students (S3) were able to perform mental rotation without detailed sketches, effectively integrating gesture simulation with mental visualization.

The effectiveness of visual learning style, which was equivalent, was demonstrated through the ability to create well-organized visual representations. However, limitations were revealed in mental rotation tasks, where static visual representations could not capture the dynamic nature of rotation transformations. This is consistent with Maftuh & Alisya (2023) findings that visual students need scaffolding for dynamic spatial transformation tasks.

The ineffectiveness of auditory learning style was caused by internal verbalization strategies being inadequate for non-verbal spatial tasks. Qualitative analysis showed that auditory students (S1) failed in visualization and rotation tasks despite trying various verbal strategies. These findings are consistent with Sheromova et al. (2020), who stated that auditory students experience difficulties in tasks requiring non-verbal spatial representation.

Characteristics of Learning Styles in Developing Spatial Reasoning Characteristics of Auditory Students

In-depth analysis of S1 revealed strong dependence on internal verbalization when solving spatial problems. The student consistently relied on verbal descriptions and step-by-step linguistic processing to mentally manipulate geometric objects. Figure 1 shows S1's work on the problems, illustrating the systematic written notes and verbal cues used throughout the problem-solving process.



Figure 1. S1's Work on The Problems

S1 succeeded in spatial perception using a combination of minimal sketches and verbalization but failed in spatial visualization and spatial rotation. Minimal use of visual sketches and dependence on verbal explanations were major limitations.

In spatial perception, S1 stated “*Saya coba gambar dulu wadahnya, terus saya membayangkan dan menjelaskan ke diri saya sendiri*” (I tried to draw the container first, then I imagined and explained to myself) This strategy was effective for simple tasks that could be linked to everyday experiences. However, in spatial visualization, S1 revealed “*Saya susah ngebayangin Pak kalau kertas itu dilipat jadi kubus*” (I have difficulty imagining how the paper is folded into a cube), indicating difficulty visualizing complex transformations.

These findings reinforce Osman et al. (2024) research that auditory individuals experience difficulty processing complex visual information without adequate verbal explanation. Pedagogical implications include the need for structured verbal scaffolding and integration of verbal explanations with concrete manipulation or interactive visual media.

Characteristics of Visual Students

S2 showed strong dependence on external visual representations. S2 consistently made detailed sketches on all problems, which facilitated success in spatial perception and spatial visualization. Figure 2 shows S2's work on the problems.

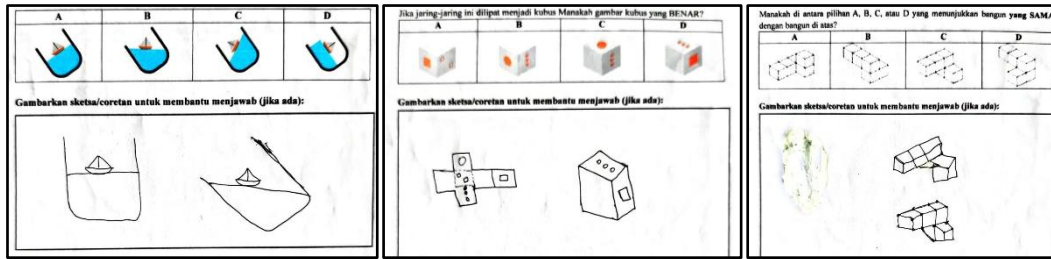


Figure 2. S2's Work on The Problems

In spatial perception, S2 made two comparative sketches showing the container in different positions, helping to compare situations. In spatial visualization, S2 made sketches of the cube net and three-dimensional cube, facilitating visualization of the folding process.

However, limitations were revealed in spatial rotation. S2 revealed “*Kalau bangun ruang diputar gitu, susah gambarnya di kertas*” (When the three-dimensional object is rotated, it's difficult to draw on paper), showing the limitations of two-dimensional media to represent three-dimensional rotation. Despite trying various strategies, mental visualization, cube counting, making sketches, S2 still experienced difficulties.

Success in two components and difficulty in rotation are consistent with Danişman & Erginer (2017) research that although visual learning style is positively correlated with spatial reasoning, mental rotation ability requires more than visual preference. Pedagogical implications include the need for dynamic visual media such as 3D animations or augmented reality to support the transition from static to dynamic visualization.

Characteristics of Kinesthetic Students

S3 showed the highest strategy flexibility, integrating physical gesture simulation, mental visualization, and sketches according to task needs. This kinesthetic learner demonstrated adaptive problem-solving by seamlessly switching between different representational modes based on problem complexity. Figure 3 shows S3's work on the problems, revealing minimal reliance on detailed drawings and a strong ability to perform mental rotations through embodied cognition.

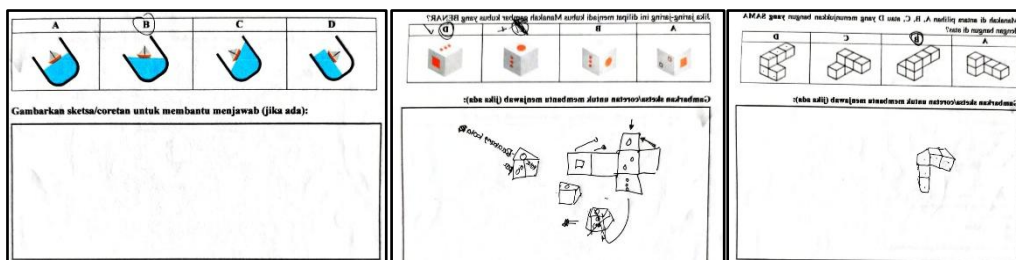


Figure 3. S3's Work on The Problems

In spatial perception, S3 used gesture simulation without sketches “*Saya langsung pakai tangan saya kayak pegang gelas, terus saya miringin*” (I immediately used my hand like holding a glass, then tilted it) In spatial visualization, S3 combined detailed sketches with mental visualization and analytical reasoning. In spatial rotation, S3 used multi-modal gesture simulation “*Saya pakai tangan saya untuk mutar-mutar bangunnya. Saya juga miringin kepala untuk lihat dari sudut yang beda-beda*” (I used my hand to rotate the object. I also tilted my head to see from different angles).

S3's advantage lies in the ability to adapt strategies based on task characteristics. Gesture strategies support the formation of strong mental representations, consistent with Lowrie et al.'s (2019) research that gestures not only reflect thinking but can also shape and change thinking. Sensorimotor experience facilitates the formation of robust mental representations about object spatial structures (Gómez-Tone et al., 2021).

Learning observations reinforced these findings: S3 was very active in manipulating teaching aids, often used hand gestures to explain understanding, and was able to explain concepts with physical demonstrations. Pedagogical implications include the need for opportunities for physical manipulation and direct exploration, as well as the use of technology such as virtual manipulatives or augmented reality that can provide kinesthetic experiences in a digital context.

Relationship Between Learning Styles and Spatial Reasoning Components

Cross-component analysis revealed different interaction patterns. For spatial perception, all three learning styles achieved success albeit with different strategies, showing that spatial perception ability is a basic ability that can be achieved by all learning styles provided they have relevant concrete experience.

For spatial visualization, only visual and kinesthetic students succeeded. This pattern indicates that spatial visualization requires the ability to form and manipulate non-verbal mental representations. Effective external representations (sketches that facilitate mental visualization) and analytical strategies (labeling to track positions) were key success factors.

For spatial rotation, only kinesthetic students succeeded, revealing that mental rotation is the most complex spatial ability. Success factors include gesture simulation to facilitate mental representation, head movements to simulate viewpoint changes, and kinesthetic experience forming long-term memory accessible for mental rotation. These findings reinforce Lowrie et al. (2019) statement that mental rotation involves construction and manipulation of mental models, and kinesthetic experience provides advantages in developing this ability.

Integration of Findings and Pedagogical Implications

The integration of quantitative and qualitative data provides comprehensive understanding of the effect of learning styles on spatial reasoning. Quantitative data show significant differences and effects, while qualitative data reveal cognitive mechanisms and strategies used.

The findings reinforce the argument that three-dimensional geometry instruction needs to accommodate learning style diversity. However, this study also reveals that each learning style has specific strengths and limitations. Therefore, instruction not only needs to accommodate learning styles but also help students develop strategies to overcome limitations.

Practical implications for instruction include:

1. Learning Style Identification. Teachers need to identify students' learning styles through appropriate assessment to design suitable learning strategies.
2. Multi-Modal Instruction. Providing various learning modalities: structured verbal explanations for auditory students, diagrams and graphic representations for visual students, and manipulative teaching aids for kinesthetic students.
3. Appropriate Scaffolding. Providing specific support: auditory students need to be trained to make visual sketches, visual students need to be trained to perform dynamic visualization, and kinesthetic students need to be trained to perform mental simulation when physical manipulation is not possible.
4. Technology Integration. The use of technology such as virtual manipulatives, 3D animations, and augmented reality can provide learning experiences that accommodate various learning styles simultaneously. Supli & Yan's (2024) research shows the effectiveness of AR in improving mental rotation skills, spatial orientation, and spatial visualization.

CONCLUSION

This study provides empirical evidence that learning style significantly affects junior high school students' spatial reasoning abilities in three-dimensional geometry

learning. Kinesthetic and visual learning styles showed almost equivalent effectiveness, and both were significantly more effective than auditory style. Each learning style has unique characteristics: auditory students rely on internal verbalization and struggle with complex visualization; visual students create detailed visual representations but are limited in dynamic transformations; kinesthetic students integrate physical gesture simulation with adaptive strategy flexibility.

The findings underscore the importance of geometry instruction that accommodates learning style diversity through various instructional modalities, appropriate scaffolding, and compensatory strategy training. The use of technology such as virtual manipulatives, 3D animations, and augmented reality is recommended to optimize spatial reasoning development across all learning styles.

Study limitations include a sample limited to one school with 30 students. Further research with larger and more diverse samples will provide stronger generalization. Future researchers can develop geometry instruction models specifically designed to accommodate learning style diversity and test their effectiveness through experimental research.

ACKNOWLEDGMENTS

This research was funded by the Directorate General of Islamic Higher Education, Ministry of Religious Affairs of the Republic of Indonesia, through the Research and Community Service Grant (Litapdimas) 2025. The author expresses sincere gratitude for this financial support.

The author would like to thank the leadership of Institut Alif Muhammad Imam Syafi'i for their continuous support and encouragement. Special appreciation is extended to the Principal, mathematics teachers, and ninth-grade students of SMP Islam Bustanul Hikmah Lamongan for their cooperation and participation in this study. Their willingness to share experiences and insights has been invaluable.

The author also acknowledges the valuable feedback from instrument validators and peer reviewers, which significantly improved the quality of this research. Finally, heartfelt thanks to family members for their unwavering support throughout the research process.

REFERENCES

- Awado, T. M., Abalos, T. J., Pelago, H. R., Morales, V., Torres, J. G., Milano, M. L., Hallarte, D. K., Gonzales, R., & Gonzales, G. (2024). Impact of teaching style on perceived mathematics achievement of elementary education preservice teachers: the mediating roles of attitude and math self-concept. *Discover Education*, 3(1). <https://doi.org/10.1007/s44217->

- Ayuningrum, L., Kusuma, A. P., & Rahmawati, N. K. (2019). Analisis Kesulitan Siswa dalam Pemahaman Belajar serta Penyelesaian Masalah Ruang Dimensi Tiga. *JKPM (Jurnal Kajian Pendidikan Matematika)*, 5(1), 135–142. <https://doi.org/10.30998/jkpm.v5i1.5277>
- Basiran, Ab., Supriadi, S., & Suroyo, S. (2021). Pengaruh Model Pembelajaran Matematika Realistik Berbantuan Alat Peraga Terhadap Kemampuan Pemahaman Geometri Ditinjau Dari Gaya Belajar Visual Spasial Siswa SD Kelas V Di Kecamatan Pasar Kemis Kabupaten Tangerang. *Jurnal Sains Sosio Humaniora*, 5(2), 1148–1154. <https://doi.org/10.22437/jssh.v5i2.16479>
- Creswell, John W Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.
- Danişman, Ş., & Erginer, E. (2017). The predictive power of fifth graders' learning styles on their mathematical reasoning and spatial ability. *Cogent Education*, 4(1). <https://doi.org/10.1080/2331186X.2016.1266830>
- Febrianti, D. A., Tambunan, E. E. B., Tarigan, G. H., Lestari, J. A., Tampubolon, S. T. V., & Siregar, B. H. (2024). Peningkatan Kemampuan Spasial Siswa SMP Negeri 17 Kelas IX Melalui Penerapan RME Berbantuan Media Interaktif GeoGebra pada Materi Transformasi Geometri. *JagoMIPA: Jurnal Pendidikan Matematika Dan IPA*, 4(3), 553–561. <https://doi.org/10.53299/jagomipa.v4i3.792>
- Fitriyah, H., & Putri, A. D. (2024). Analisis Kesulitan Belajar Matematika Materi Geometri Pada Siswa Kelas 4 Sekolah Dasar. *Jurnal Pendidikan Matematika*, 2(1), 1–8. <https://doi.org/10.58917/ijme.v2i2.64>
- Gómez-Tone, H. C., Martín-Gutierrez, J., Bustamante-Escapa, J., & Bustamante-Escapa, P. (2021). Spatial skills and perceptions of space: Representing 2D drawings as 3D drawings inside immersive virtual reality. *Applied Sciences*, 11(4), 1475. <https://doi.org/10.3390/app11041475>
- Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice.". *Field Methods*, 18(1), 3–20. <https://doi.org/10.1177/1525822X05282260>
- Lokollo, L. J., Lasaiba, M. A., Arfa, A. M., & Lasaiba, D. (2024). Mengembangkan Kemampuan Berpikir Spasial Melalui Pendidikan STEM di Sekolah Dasar. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, 14(3), 293–308. <https://doi.org/10.47134/ppm.v2i1.1112>
- Lowrie, T., & Diezmann, C. M. (2007). Solving Graphics Problems: Student Performance in Junior Grades TOM. *The Journal of Educational Research*, 100(6), 369–378. <https://doi.org/10.3200/JOER.100.6.369-378>
- Lowrie, T., Logan, T., & Hegarty, M. (2019). The Influence of Spatial Visualization Training on Students' Spatial Reasoning and Mathematics Performance. *Journal of Cognition and Development*, 20(5), 729–751. <https://doi.org/10.1080/15248372.2019.1653298>
- Maftuh, M. S., & Alisya, T. N. (2023). Level Kemampuan Penalaran Spasial Siswa SMA dengan Gaya Belajar Visual dalam Menyelesaikan Masalah Geometri. *MENDIDIK: Jurnal Kajian Pendidikan Dan Pengajaran*, 9(2), 222–231. <https://doi.org/10.30653/003.202392.16>
- Maftuh, M. S., & Ni'mah, A. W. (2023). Level Kemampuan Penalaran Spasial Siswa SMA dengan Gaya Belajar Kinestetik dalam Menyelesaikan Masalah Geometri. *Jurnal Simki Pedagogia*, 6(1), 435–447. <https://doi.org/10.29407/jsp.v6i2.250>
- Mahadi, F., Husin, M. R., & Md, H. N. (2022). Gaya Pembelajaran: Visual, Auditori dan Kinestetik. *Journal of Humanities and Social Sciences*, 4(1), 29–36.

<https://doi.org/10.36079/lamintang.jhass-0401.340>

- Milles, M. B., & Huberman, A. M. (1994). *Qualitative and Analysis* (2nd Ed). UI Press.
- Oktavianto, D. A. (2022). Pengaruh Project-Based Learning Berdiferensiasi dengan Aktivitas Inkuiri Geografis Terhadap Peningkatan Keterampilan Berpikir Spasial Siswa. *Jurnal TEKNODIK*, 26(2), 145–156. <https://jurnalteknodik.kemdikbud.go.id/index.php/jurnalteknodik/article/view/1015/515>
- Osman, N. W., Wan Salleh, W. M. N. H., & Taha, H. (2024). Kajian Korelasi Gaya Pembelajaran Visual, Auditori, dan Kinestetik Terhadap Kemahiran Berfikir Aras Tinggi (KBAT) Pelajar dalam Topik Respirasi. *Jurnal Pendidikan Sains Dan Matematik Malaysia*, 14(1), 29–37. <https://doi.org/10.37134/jpsmm.vol14.1.3.2024>
- Ramful, A., Lowrie, T., & Logan, T. (2017). Measurement of Spatial Ability: Construction and Validation of the Spatial Reasoning Instrument for Middle School Students. *Journal of Psychoeducational Assessment*, 35(7), 709–727. <https://doi.org/10.1177/0734282916659207>
- Riyanto, O. R., Widyastuti, Yustitia, V., Oktaviyanthi, R., Sari, N. H. M., Izzati, N., Sukmaangara, B., Indartiningsih, D., Wibowo, A., Maharbid, D. A., & Wahid, S. (2024). *Kemampuan Matematis* (Issue July). CV. Zenius Publisher.
- Septian, A., Fahrisyah, M. L., & Jusniani, N. (2022). Pengembangan GeoGebra Classroom Pada Materi Transformasi Geometri. *Prisma*, 11(2), 504–514. <https://doi.org/10.35194/jp.v11i2.2483>
- Sheromova, T. S., Khuziakhmetov, A. N., Kazinets, V. A., Sizova, Z. M., Buslaev, S. I., & Borodianskaia, E. A. (2020). Learning styles and development of cognitive skills in mathematics learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(11). <https://doi.org/10.29333/EJMSTE/8538>
- Silaban, R. A., Ilahi, A., Effendi, Sari, N., Truelovin H.P, R., Syarifah, H., AlIkhlas, Amrullah, A. K., Ningsih, R. W., Setyorini, I., Rodin, R., Ratih Permana Sari, Hilyana, F. S., Effendi, H., Sobirin, M. A., & Sinaga, D. (2024). *Gaya Belajar Peserta Didik*. Penerbit Mifandi Mandiri Digital.
- Sugianto, A. (2021). Kuesioner Gaya Belajar Siswa. *Repo-Dosen.Ulm.Ac.Id*, 1–6. [https://repositori.uhm.ac.id/bitstream/handle/123456789/26041/Angket Gaya Belajar 2021.pdf?sequence=1](https://repositori.uhm.ac.id/bitstream/handle/123456789/26041/Angket_Gaya_Belajar_2021.pdf?sequence=1)
- Xie, F., Zhang, L., Chen, X., & Xin, Z. (2020). Is Spatial Ability Related to Mathematical Ability: a Meta-analysis. *Educational Psychology Review*, 32(1), 113–155. <https://doi.org/10.1007/s10648-019-09496-y>