



Spatial-Visual Ability Profiles Across Mathematics Achievement Levels: Identifying Key Discriminating Dimensions

Jelita Fuji Khaebibah, Wahyu Hartono*, Tri Nopriana

Mathematics Education Department, Faculty of Education and Science,
Universitas Swadaya Gunung Jati, Indonesia.

*Corresponding Author. Email: wahyuhartono@ugj.ac.id

Abstract: This study aims to describe students' spatial-visual ability profiles across different levels of mathematics achievement, examine differences among high-, medium-, and low-achievement groups, and identify the spatial-ability dimension that most clearly distinguishes these groups. This mixed-methods study employed a sequential explanatory design involving 65 eleventh-grade students selected through purposive sampling. Quantitative data were collected using a spatial-visual ability test and analyzed using descriptive statistics, the Kruskal–Wallis test, effect size estimation, and pairwise comparisons with Bonferroni correction. Qualitative data were obtained through questionnaires and semi-structured interviews with nine students selected using maximum variation sampling and were analyzed thematically. The results showed that students in the high- and medium-achievement groups obtained nearly identical mean scores (76.08 and 76.19, respectively), whereas the low-achievement group obtained a substantially lower mean score (39.40). The Kruskal–Wallis test revealed significant differences among the three groups, $H(2) = 13.768$, $p = .001$, with a medium effect size ($\epsilon^2 = .190$). Pairwise comparisons showed significant differences between the low- and high-achievement groups ($p = .014$) and between the low- and medium-achievement groups ($p = .003$), but not between the high- and medium-achievement groups ($p = .913$). Spatial visualization emerged as the most distinctive dimension, particularly in multi-step transformation tasks. These findings contribute to mathematics education by demonstrating that achievement-based grouping may mask distinct spatial-visual ability profiles.

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Introduction

Transformation is a core topic in school mathematics because it requires students to coordinate symbolic rules with spatial-visual reasoning. Unlike conventional plane or solid geometry, transformation tasks require learners to mentally track changes in position, direction, orientation, and scale through one or more operations. This dynamic and abstract character makes spatial-visual reasoning central to understanding higher-order geometric concepts and solving transformation problems. Geometric transformation (translation, reflection, rotation, dilation) is a one-to-one mapping on a plane (Nurwita et al., 2025; Thomas, 1976). Students often experience difficulty determining rotation direction and angle, locating reflected points, interpreting coordinate changes, and completing multi-step transformation compositions (Hafizh & Kusno, 2025). These difficulties appear in orientation errors, inaccurate point placement, and the use of procedures without conceptual understanding.



These difficulties are closely related to students' ability to process visual and spatial information. Although students with visual learning preferences need visual representations (Oktaviana et al., 2022), and visual, auditory, and kinesthetic learning styles are related to mathematics learning outcomes (Khoirunnisa & Iba, 2022), learning-style explanations alone are insufficient. Geometric transformation specifically requires spatial-visual ability, namely the ability to understand, represent, and mentally manipulate spatial information.

Geometry, particularly geometric transformation, is highly relevant to 21st-century demands because it trains critical thinking, analytical skills, and complex problem solving (Amalia et al., 2025; Hidayah et al., 2025; Orrissa & Suwarno, 2024; Rahman, 2025). Problem-based geometry learning improves critical thinking (Amalia et al., 2025), while students with high spatial-visual intelligence tend to use systematic reasoning and mental imagery (Hidayah et al., 2025). Geometric transformation is more effectively taught through visual approaches to build mental representations (Mashingaidze, 2012). Visualization media, including three-dimensional media, function as cognitive scaffolds in supporting students' spatial-visual representations and mental transformations (Disman & Gunawan, 2026).

Spatial-visual ability is defined as the ability to understand, represent, and manipulate objects in space mentally (Erfansyah et al., 2023; Hariri et al., 2025; Kus & Newcombe, 2025; Nolte et al., 2025; Yang et al., 2025). Linn & Petersen (1985) divided this ability into three aspects: mental rotation, spatial visualization, and spatial perception. These three aspects complement each other in geometry tasks (Lochhead et al., 2022; Lowrie & Logan, 2023; Piri & Cagiltay, 2024). Mental rotation plays a role when students imagine object rotation, spatial visualization when manipulating objects through several transformation steps, and spatial perception for understanding position, direction, and orientation of objects relative to a reference. This ability is not a fixed talent; it can be improved through structured practice and appropriate visual media (Izzati et al., 2024; Uttal et al., 2024).

Students' abilities in a single classroom are diverse and can be reviewed from academic achievement. Inclusive education encompasses diversity of abilities, including differences in achievement (Prediger, 2024; Prediger & Neugebauer, 2023). Academic achievement is often used as an indicator of material mastery, learning strategies, and accuracy (Hasanah et al., 2022). However, in the context of geometric transformation, achievement does not necessarily reflect spatial-visual ability specifically (Harris et al., 2023; Shaghaghian et al., 2024). Some high-achieving students solve problems through memorizing formulas, while others may have good visual potential but lack accuracy or consistency.

Many students memorize formulas for rotation and reflection rather than using a visual approach (Shaghaghian et al., 2024), whereas digital visualization can improve spatial reasoning (Fitriawan et al., 2026). Affective and environmental factors also influence success; beliefs that mathematics is difficult are influenced by family, teachers, and peers (Purbaningrum et al., 2023). The relationship between achievement and spatial-visual ability warrants more specific examination in the context of geometric transformation.

These conditions indicate three research gaps. First, studies on students' spatial-visual ability are still mostly situated in general geometry, whereas the abstract and dynamic nature of geometric transformation requires separate analysis because students must mentally sustain and manipulate objects through sequential changes. Second, mathematics achievement has not been widely examined to determine whether high-, medium-, and low-achievement categories show different spatial-visual profiles. Third, studies integrating quantitative and qualitative evidence to identify the spatial-visual dimension that most clearly distinguishes achievement groups remain limited.



This study aims to: (1) describe students' spatial-visual ability profiles across high-, medium-, and low-achievement categories; (2) examine differences in spatial-visual ability among these categories; and (3) identify the spatial-visual aspect that most clearly distinguishes them. The contribution of this study lies in demonstrating that mathematics achievement may conceal different spatial-visual profiles, thereby distinguishing procedural performance from spatial intuition in geometric transformation learning.

Research Method

This study employed a mixed-methods approach with a sequential explanatory design (Creswell & Plano Clark, 2007). The quantitative phase described and tested differences in spatial-visual ability based on mathematics academic achievement, while the qualitative phase used questionnaires and interviews to explain students' strategies, difficulties, and errors. This study was also ex post facto comparative because it analyzed differences based on existing achievement categories without treatment manipulation (Lantu et al., 2025).

The participants were 65 eleventh-grade students in Cirebon who had studied geometric transformation. They were selected using purposive sampling based on curriculum suitability and the availability of mathematics grade data. Students were grouped into high (≥ 85), medium (75–84), and low (< 75) categories based on the school minimum mastery criterion of 75. For the qualitative phase, nine students were selected using maximum variation sampling, representing each achievement category and contrasting spatial-visual scores, including typical and extreme cases. The study was conducted after school permission was granted, and students' identities were kept confidential.

The instrument was validated through expert judgement by two mathematics education lecturers and one experienced mathematics teacher, covering indicator suitability, language clarity, difficulty level, and image quality. Data were collected through documentation of mathematics grades, a six-item spatial-visual ability essay test, questionnaires, and semi-structured interviews. The test measured mental rotation (items 1–2), spatial visualization (items 3–4), and spatial perception (items 5–6) using a tiered scoring rubric. The instrument was validated through expert judgement by two mathematics education lecturers and one experienced mathematics teacher. Cronbach's Alpha was 0.87, indicating high internal consistency in line with reliability reporting in educational instrument development (Taber, 2018). Visual scores were categorized as high (≥ 70), medium (40–69), and low (< 40). Quantitative data were analyzed using descriptive statistics, the Shapiro-Wilk normality test, the Kruskal-Wallis test, and pairwise comparisons with Bonferroni correction. Qualitative data were analyzed thematically through data reduction, data display, and conclusion drawing (Miles et al., 2014). Credibility was maintained through triangulation and member checking, and integration of quantitative and qualitative data was conducted in the discussion phase.

Results and Discussion

This study involved 65 eleventh-grade students grouped into three mathematics academic achievement categories: high, medium, and low. The distribution of students is presented in Table 1.

Table 1. Distribution of Students Based on Mathematics Academic Achievement Categories

Academic Achievement Category	Frequency (N)	Percentage (%)
High	24	36,9%
Medium	16	24,6%



Low	25	38,5%
Total	65	100%

Table 1 indicates that all achievement categories were represented, although the distribution was not balanced. The largest group was the low-achievement category, which is important because it allows the analysis to capture spatial-visual difficulties among students who are most vulnerable in geometric transformation tasks. Descriptive statistics of spatial-visual ability based on achievement categories are presented in Table 2.

Table 2. Spatial-Visual Scores Based on Mathematics Academic Achievement Categories

Academic Achievement Category	N	Average	Standard Deviation	Minimum	Maximum
High	24	76.08	27.54	0	100
Medium	16	76.19	18.66	40	100
Low	25	39.40	29.17	0	95
Total	65	61.18	30.92	0	100

Table 2 highlights two important patterns. First, the high- and medium-achievement groups showed nearly identical mean scores, suggesting that higher academic achievement does not automatically indicate stronger spatial-visual ability. Second, the relatively large standard deviations in the high and low groups indicate substantial within-group variation, meaning that both groups contained students with contrasting spatial-visual profiles.

Table 3. Cross-Tabulation of Achievement Categories and Visual-Spatial Categories

Academic Achievement Category	High Visual	Medium Visual	Low Visual	Total
High	13 (54.2%)	6 (25.0%)	5 (20.8%)	24
Medium	7 (43.8%)	5 (31.2%)	4 (25.0%)	16
Low	2 (8.0%)	8 (32.0%)	15 (60.0%)	25
Total	22	19	24	65

Table 3 further confirms that the relationship between achievement and spatial-visual ability was not absolute. Although the low-achievement group was dominated by students with low visual scores, two low-achieving students still reached the high visual category, while several high-achieving students remained in the low visual category. This pattern suggests that achievement categories alone cannot fully represent students' spatial-visual profiles.

Table 4. Visual-Spatial Ability Scores per Aspect Based on Mathematics Academic Achievement Categories

Aspect	Question Number	Maximum Score	High Mean	Medium Mean	Low Mean	High-Low Difference
Mental Rotation	1–2	32	25.83	25.00	12.67	13.16
Spatial Visualization	3–4	34	26.08	26.50	12.89	13.19
Spatial Perception	5–6	34	24.17	24.69	13.85	10.32
Total	1–6	100	76.08	76.19	39.40	36.68

Table 4 shows a consistent gap between the low-achievement group and the other two groups across all spatial-visual aspects. The largest high–low difference appeared in spatial visualization (13.19), followed very closely by mental rotation (13.16). Thus, spatial visualization should be interpreted as an important distinguishing aspect particularly when it is connected with the qualitative evidence from multi-step transformation tasks.



Before conducting the between-group difference test, the data were tested for normality using Shapiro-Wilk. The normality test results revealed that the low achievement group ($p=0.089$) and medium achievement group ($p=0.071$) had normally distributed data ($p > 0.05$). However, the high achievement group data were not normally distributed ($p=0.008 < 0.05$). Therefore, the Kruskal-Wallis non-parametric test was used to examine differences in spatial-visual ability among academic achievement categories. The results are presented in Table 5.

Table 5. Results of Kruskal-Wallis Test

N	Test Statistic (H)	df	Asymp. Sig. (2-tailed)	α	Decision
65	13.768	2	0.001	0.05	Reject H_0

Based on Table 5, $H(2)=13.768$ with $p=0.001$ (<0.05), so H_0 was rejected. The mean ranks showed that the low group occupied the lowest position, while the medium group slightly exceeded the high group. The effect size was $\varepsilon^2=0.190$, indicating a medium effect and suggesting that achievement categories were meaningfully associated with differences in spatial-visual ability.

Table 6. Results of Pairwise Comparisons with Bonferroni Correction

Comparison	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adjusted Sig.	Conclusion
Low – High	-14.667	5.200	-2.821	0.005	0.014	Significant
Low – Medium	-21.482	6.520	-3.295	<0.001	0.003	Significant
High – Medium	6.815	6.636	1.027	0.304	0.913	Not Significant

**Significance adjusted with Bonferroni correction. Significance level $\alpha = 0.05$.*

Based on Table 6, there were significant differences between low and high ($p=0.014$) and low and medium ($p=0.003$), but not between high and medium ($p=0.913$). The main difference occurred between the low group and the other two groups, while high and medium were relatively comparable. To deepen the quantitative findings, qualitative data were collected through questionnaires and interviews with nine selected students, considering variations in spatial-visual scores within each achievement category. Characteristics of interview subjects are presented in Table 7.

Table 7. Characteristics of Interview Subjects

Code	Category	Achievement Score	Visual Score	Key Characteristics
T1	High	100	24	Relies on formula memorization; low visualization
T2	High	93	99	Very high visualization; nearly perfect solutions
T3	High	95	76	Good visualization; needs improved accuracy
S1	Medium	84	93	High visualization; lower score due to inaccuracy
S2	Medium	78	82	Fairly balanced; difficulty with reflection
S3	Medium	83	72	Good visual score; still often forgets formulas
R1	Low	29	0	No visual strategy demonstrated in the test
R2	Low	35	52	Limited visualization; some basic ability
R3	Low	18	0	No adequate visual strategy shown in the test



Thematic analysis of interview and questionnaire data produced four main themes.

Theme 1: Dependence on Formulas versus Use of Visualization

This theme revealed differences in strategy between students who relied on symbolic procedures and those who used visualization. Subject T1 (high achievement) showed that procedural mastery was not always accompanied by strong visual understanding: "Understand the concept... do not be like me, who only memorized formulas." (T1) In contrast, T2 used an integrated visual strategy: "I adjust to the problem instructions; if I am asked to draw, then I will imagine the result." (T2) This contrast suggests that academic achievement does not always reflect students' spatial-visual strategies.

Theme 2: Difficulty Imagining Transformation Results

This difficulty was evident among low-achieving students, especially when images were not available. R1 stated, "I am generally confused if there is no image." (R1) This statement indicates that images functioned as important visual aids for students with low spatial-visual ability. R3 added, "I understand somewhat, but I forgot the material because I had a lot on my mind that day." (R3) These responses show that students' understanding of transformations was not yet stable enough for independent problem solving.

Theme 3: Errors in Transformation Composition

Transformation composition was the most challenging part for students with low spatial-visual ability. R2 stated, "Determining the image was difficult." (R2) Students often lost track of object position after the first stage. In contrast, students with higher visual scores, such as S1, could imagine the transformation sequence: "For question number 3, the first stage is dilation by 3 from the center, so it is multiplied by 3." (S1) This evidence supports the role of spatial visualization in multi-step tasks.

Theme 4: The Role of Images as Visual Aids

High- and medium-achievement students tended to use images as supplements, whereas low-achievement students were highly dependent on them. R1 stated, "I am generally confused if there is no image." (R1) S2 emphasized the need for accuracy: "Drawing takes a long time, and determining points must be done carefully so that they are not reversed." (S2) Thus, images supported understanding but still required coordinate accuracy.

Discussion

Profile of Spatial-Visual Ability Based on Mathematics Academic Achievement

The results demonstrate that high- and medium-achievement students had comparable spatial-visual means, whereas the low-achievement group scored much lower. This finding is consistent with Mulianah et al. (2025), who showed that spatial-visual intelligence positively influences geometric transformation achievement. At a theoretical level, the present study contributes to global mathematics education literature by showing that achievement-based grouping can mask distinct cognitive profiles in geometry learning.

The findings reveal a contrast between procedural encapsulation and spatial intuition. Some high-achieving students, represented by T1, relied heavily on memorized formulas and symbolic procedures but showed weak visualization. By contrast, some medium-achieving students, represented by S1, demonstrated strong spatial intuition but lost marks because of algebraic or procedural inaccuracy. This distinction supports the argument that spatial-visual ability should be treated as a specific analytical dimension, not merely as a by-product of academic achievement.

These findings align with Shaghaghian et al. (2024), who reported that students often solve rotation and reflection tasks through formula memorization rather than meaningful



visual approaches. Procedural strategies may be sufficient for routine items, but they are less adequate for tasks requiring mental representation, orientation changes, and multi-step compositions.

Differences in Spatial-Visual Ability Among Achievement Groups

The Kruskal-Wallis test revealed significant differences in spatial-visual ability among mathematics academic achievement categories. However, follow-up tests showed that these differences occurred primarily between the low achievement group and the other two groups, while the high and medium groups did not differ significantly. This pattern indicates that low-achieving students face more pronounced spatial-visual barriers than students in the high and medium categories.

The significant difference between the low group and the other two groups indicates spatial-visual ability as an important prerequisite in geometric transformation. Students with low spatial-visual ability have difficulty building mental representations, maintaining object position, and connecting images with coordinate procedures. This corroborates Ningsih et al. (2021), who stated that low spatial literacy can cause difficulties in geometry problem solving. This finding also lends support to Hafizh & Kusno (2025), that weak abstraction and visualization are causes of difficulty in geometric transformation.

The non-significant difference between the high and medium groups indicates that academic achievement is not the main differentiator of spatial-visual ability. Teachers therefore need to identify students who are procedurally strong but visually weak, as well as students who have strong visual potential but need support in algebraic accuracy and written procedures.

Spatial-Visual Aspect That Most Distinguishes Students

Based on per-aspect scores, spatial visualization showed the highest difference between high and low groups, followed very closely by mental rotation. Therefore, spatial visualization cannot be declared dominant based solely on quantitative differences. However, when linked to qualitative data, spatial visualization appears to best explain students' difficulties in multi-step composition problems.

According to Linn & Petersen (1985), spatial visualization is the ability to manipulate spatial configurations through complex mental steps, different from mental rotation (object rotation) and spatial perception (recognition of relative position). Low-achieving students' difficulties are most evident when maintaining object position after the first stage, seen in R1, R2, and R3 who lost track in transformation composition. In contrast, high spatial-visual students like T2 and S1 were able to imagine the transformation sequence before writing procedures. Success in geometric transformation depends on the ability to maintain and manipulate mental imagery in stages (Hawes et al., 2022). Spatial visualization is the most prominent aspect interpretively because its role is strong in tests, interviews, and error patterns.

Implications for Geometric Transformation Learning

These findings have several practical implications. First, low-achieving students need gradual visualization practice from single transformations to transformation compositions. Teachers can ask students to predict images before calculating coordinates and then compare predictions with formal procedures to build connections between visual and symbolic representations.

Second, instruction should adopt a dual-coding orientation by connecting visual-spatial representations with coordinate, matrix, and algebraic notation (Paivio, 1991). Dynamic visual media such as GeoGebra can help students understand changes in position,



orientation, and shape (Rizzik et al., 2025), while three-dimensional visualization media can function as cognitive scaffolds for spatial representations and mental transformations (Disman & Gunawan, 2026). Media use should emphasize students' thinking processes rather than only demonstrating final results.

Fourth, teachers need to consider technology use selectively. Fineldi et al. (2026) showed that ChatGPT can function as procedural and elaborative scaffolding, but does not automatically encourage divergent thinking. In addition to digital technology, non-digital media such as "Space Capsule" can also be used to train spatial visualization skills, especially in schools with limited access to digital technology (Alia et al., 2026). Media selection must align with objectives, student characteristics, and school conditions, and should not replace students' visual thinking processes.

Conclusion

Based on the research findings, it can be concluded that students' spatial-visual ability in solving geometric transformation problems differs according to academic achievement categories. High and medium achievement students demonstrated comparable spatial-visual means, while low achievement is much lower. The relationship between achievement and spatial-visual ability is not deterministic; some high-achieving students still have visualization limitations, while some medium-achieving students have strong spatial-visual ability. The Kruskal-Wallis test revealed significant differences among categories ($H(2)=13.768$, $p=0.001$, $\varepsilon^2=0.190$). The main difference occurs between the low group and both high and medium groups, while high and medium do not differ significantly. Low spatial-visual ability is an important barrier for low-achieving students.

Among the three aspects, spatial visualization emerged as the most prominent in explaining differences in student strategies and difficulties, especially in multi-step compositions. Students with strong visualization maintained mental imagery through multiple stages, while students with low visualization lost track after the first stage. These findings reinforce the need for gradual visualization practice, dynamic representations, and dual connections among images, concepts, coordinate procedures, and algebraic notation.

Recommendation

Based on the findings, teachers should design geometric transformation learning that develops spatial-visual ability through dual-coding instruction. Learning can begin with predicting object images, drawing transformation results, comparing predictions with coordinate calculations, and gradually solving transformation compositions. Teachers should explicitly connect visual-spatial representations with matrix and algebraic notation so that students understand both the movement of objects and the symbolic structure of transformations.

For students with low mathematics achievement, teachers need to provide simple visualization exercises before introducing more complex composition transformation problems. For medium-achieving students, learning can be directed toward improving accuracy, procedural consistency, and strengthening the connection between images and coordinates. Meanwhile, high-achieving students can be given more challenging transformation tasks to develop visual and procedural abilities in balance.

Future researchers are encouraged to develop more separated spatial-visual instruments to measure mental rotation, spatial visualization, and spatial perception in more detail. Further research can also use experimental or pretest-posttest designs to test the



effectiveness of visualization-based learning interventions on students' spatial-visual ability in geometric transformation

References

- Agustina, L. A., & Masyithoh, S. (2025). Pengaruh lingkungan sekolah terhadap prestasi belajar siswa di sekolah dasar: Tinjauan literatur. *Jurnal Pendidikan Dan Keguruan*, 3(3), 692–702.
- Alia, H., Lisnani, L., Widyawati, H., Walker, J., & Azhar, R. H. (2026). Integrated Non-Digital Media Innovation 'Space Capsule' to Train Spatial Visualization Skills in Solid Geometry for Students. *Mosharafa: Jurnal Pendidikan Matematika*, 15(1), 311–323. <https://doi.org/10.31980/mosharafa.v15i1.3551>
- Anisa, U. I., Suanto, E., Yuanita, P., & Maimunah, M. (2023). Analisis Kesalahan Siswa pada Pembelajaran Matematika Berdasarkan Teori Newman dalam Menyelesaikan Soal SPLDV. *Jurnal Paedagogy*, 10(1), 250. <https://doi.org/10.33394/jp.v10i1.6496>
- Creswell, J. W. , & Plano Clark, V. L. (2007). Designing and Conducting Mixed Methods Research. In *Library & Information Science Research* (Vol. 29, Number 3). SAGE. <https://doi.org/10.1016/j.lisr.2007.02.001>
- Disman, & Gunawan. (2026). The Influence of Three-Dimensional Visualization Media on Spatial Skills and Creative Thinking of Elementary School Students. *Desimal: Jurnal Matematika*, 9(2), 134–154. <https://doi.org/10.24042/djm.v9i1>
- Orrissa, R. D., & Suwarno. (2024). Skepticism of Students Participating in National Science Olympiad in Solving Geometry Problems across Gender Differences. *Jurnal Pendidikan MIPA*, 25(1), 496–511. <https://doi.org/10.23960/jpmipa/v25i1.pp496-511>
- Erfansyah, M., Munzir, S., & Johar, R. (2023). Kemampuan Spasial Siswa Di Daerah Pedesaan Ditinjau Dari Perbedaan Gender. *JUMPER: Journal of Educational Multidisciplinary Research*, 2(2), 1–12. <https://doi.org/10.56921/jumper.v2i2.82>
- Fineldi, R. J., Jupri, A., & Khatami, M. (2026). Exploring the Role of ChatGPT in Enhancing Students' Mathematical Creative Thinking in Geometry Learning: A Qualitative Case Study. *Mosharafa: Jurnal Pendidikan Matematika*, 15(1), 149–164. <https://doi.org/10.31980/mosharafa.v15i1.3567>
- Fitriawan, D., Siregar, N., Hartoyo, A., & Sulistyowati, E. (2026). Developing STEM integrated analysis geometry learning materials through digital visualization and e-learning platforms. *Al-Jabar : Jurnal Pendidikan Matematika*, 17(1), 91–105. <https://doi.org/10.24042/ajpm.v17i1.29388>
- Hafizh F. A., & Kusno. (2025). Analisis kesulitan berpikir abstrak siswa dalam materi transformasi geometri: Studi kualitatif pada siswa SMP. *Jurnal Ilmiah Pendidikan Citra Bakti*, 12(2), 570–584. <https://doi.org/10.38048/jipcb.v12i2.5367>
- Hariri, D. D., Mahmudah, H., Wibawa, F. S., & Kania, N. (2025). Unraveling the connection: A systematic review of learning styles and mathematics achievement. In *Pedagogical Research* (Vol. 10, Number 1). Modestum. <https://doi.org/10.29333/pr/15681>
- Harris, D., Logan, T., & Lowrie, T. (2023). Spatial visualization and measurement of area: A case study in spatialized mathematics instruction. *The Journal of Mathematical Behavior*, 70. <https://doi.org/10.1016/j.jmathb.2023.101038>
- Hasanah, H., Farida, A., & Yoga, P. P. (2022). Implementation of Simple Linear Regression for Predicting of Students' Academic Performance in Mathematics. *Jurnal*



- Pendidikan Matematika (Kudus), 5(1), 39–52.
<https://doi.org/10.21043/jpmk.v5i1.14430>
- Hawes, Z. C. K., Gilligan-Lee, K. A., & Mix, K. S. (2022). Effects of Spatial Training on Mathematics Performance: A Meta-Analysis. *Developmental Psychology*, 58(1), 112–137. <https://doi.org/10.1037/dev0001281>
- Hidayah, H., Riyadi, R., & Matsuri, M. (2025). The Role of Spatial Visual Intelligence in the Problem Solving Process of Building Spatial Geometry. *Social, Humanities, and Educational Studies (SHEs): Conference Series*, 8, 13–21. <https://doi.org/10.20961/shes.v8i4.109327>
- Izzati, N., Widyastuti, W., & Nurhadiansyah, N. (2024). Improving Students' Mathematical Spatial Ability in the Spatial Geometry Course Using GeoGebra. *Journal of Mathematics Instruction, Social Research and Opinion*, 3(3), 389–398. <https://doi.org/10.58421/misro.v3i3.331>
- Khoirunnisa, S., & Iba, K. (2022). Correlation Study Of Visual, Auditorial and Kinesthetic Learning Styles (VAK) With Mathematics Learning Outcomes For Elementary School Students. *Jurnal Paedagogy*, 9(4), 790. <https://doi.org/10.33394/jp.v9i4.5495>
- Kus, M., & Newcombe, N. S. (2025). Facilitation of students' disembedding in an online visual arts and mathematics education program. *International Journal of STEM Education*, 12(1). <https://doi.org/10.1186/s40594-024-00524-0>
- Linn, M. C., & Petersen, A. C. (1985). Emergence and Characterization of Sex Differences in Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis Spatial Ability: A Meta-Analysis. *Child Development*, 56(6), 1479–1498. <https://doi.org/10.2307/1130467>
- Lochhead, I., Hedley, N., Çöltekin, A., & Fisher, B. (2022). The Immersive Mental Rotations Test: Evaluating Spatial Ability in Virtual Reality. *Frontiers in Virtual Reality*, 3. <https://doi.org/10.3389/frvir.2022.820237>
- Lowrie, T., & Logan, T. (2023). Spatial Visualization Supports Students' Math: Mechanisms for Spatial Transfer. *Journal of Intelligence*, 11(6). <https://doi.org/10.3390/jintelligence11060127>
- Margaret Spellings. (1994). *Helpin g Your Child Learn Mathematics*. www.edpubs.org/webstore/Content/search.asp
- Mashingaidze, S. (2012). The teaching of geometric (isometric) transformations at secondary school level: What approach to use and why? *Asian Social Science*, 8(15), 197–210. <https://doi.org/10.5539/ass.v8n15p197>
- Montague, M. (2008). Hammill Institute on Disabilities Self-Regulation Strategies to Improve Mathematical Problem Solving for Students with Learning Disabilities. *Learning Disability Quarterly*, 31(1), 37–44. <https://doi.org/10.2307/30035524>
- Mulianah, M., Thalib, A., Habsyi, R., & Ahmad, K. A. (2025). Pengaruh Kecerdasan Logis Matematis, Interpersonal, Visual Spasial, Dan Eksistensial Terhadap Prestasi Belajar Transformasi Geometri. *Jurnal Ilmiah Matematika (JIMAT)*, 6(2), 668–680.
- Nolte, N., Fleischer, J., Spoden, C., & Leutner, D. (2025). Cross-Disciplinary Impact of Spatial Visualization Ability on Study Success in Higher Education. *Journal of Educational Psychology*, 117(5), 817–831. <https://doi.org/10.1037/edu0000847.supp>
- Ningsih, I. P., Budiarto, M. T., & Khabibah, S. (2021). Literasi spasial siswa SMP dalam menyelesaikan soal geometri ditinjau dari perbedaan gaya belajar. *AKSIOMA*:



- Jurnal Program Studi Pendidikan Matematika*, 10(3), 1531.
<https://doi.org/10.24127/ajpm.v10i3.3650>
- Nurhidayah, A., Mawarsari, V. D., & Suprpto, R. (2025). Systematic Literature Review : Penggunaan Media Articulate Storyline Dalam Kemampuan Berpikir Geometri Siswa SMP. *INNOVATIVE: Journal Of Social Science Research*, 5, 6866–6885.
- Nurwita, F., Kusumah, Y. S., & Juandi, D. (2025). Design and evaluation of a mobile application for achieving computational thinking skills through geometric transformation learning in middle school. *Infinity Journal*, 14(4), 877–898.
<https://doi.org/10.22460/infinity.v14i4.p877-898>
- Oktaviana, D., Maimunah, M., & Roza, Y. (2022). Analisis Kemampuan Penalaran Siswa SMP dalam Memecahkan Masalah Matematika Berdasarkan Jenis Gaya Belajar. *Jurnal Paedagogy*, 9(3), 521. <https://doi.org/10.33394/jp.v9i3.5286>
- Pebrian, M., & Bektiningsih, K. (2026). Pemberian Reward dalam Meningkatkan Semangat Belajar dan Kemampuan Berpikir Kritis Siswa Kelas V SDN Bringin 01 Kota Semarang. *Jurnal Papeda: Jurnal Publikasi Pendidikan Dasar*, 8(1), 94–102.
<https://doi.org/10.36232/jurnalpendidikandasar.v8i1.4454>
- Piri, Z., & Cagiltay, K. (2024). Can 3-Dimensional Visualization Enhance Mental Rotation (MR) Ability?: A Systematic Review. *International Journal of Human-Computer Interaction*, 40(14), 3683–3698. <https://doi.org/10.1080/10447318.2023.2196161>
- Prediger, S. (2024). Fifty ways to work with students' diverse abilities? A video study on inclusive teaching practices in secondary mathematics classrooms. *International Journal of Inclusive Education*, 28(2), 124–143.
<https://doi.org/10.1080/13603116.2021.1925361>
- Prediger, S., & Neugebauer, P. (2023). Can students with different language backgrounds profit equally from a language-responsive instructional approach for percentages? Differential effectiveness in a field trial. *Mathematical Thinking and Learning*, 25(1), 2–22. <https://doi.org/10.1080/10986065.2021.1919817>
- Purbaningrum, M., Ramadhan, S., & Thauzahra, R. (2023). Why is Math Difficult? : Beliefs That Affecting Students' Mathematics Skills. *Jurnal Paedagogy*, 10(4), 1000.
<https://doi.org/10.33394/jp.v10i4.8652>
- Lantu, F. R., Manggopa, H. K., & Batmetan, J. R. (2025). Pengaruh Aktivitas dan Motivasi Belajar terhadap Hasil Belajar Informatika Siswa di SMA Negeri 1 Remboken. *GuruNesia: Jurnal Inovasi Dan Transformasi Pendidikan Guru Nusantara*, 1(1), 1–12. <https://doi.org/10.67142/gurunesia.v1i1.181>
- Rizzik, F., Mawarsari, V. D., & Purnomo, E. A. (2025). Systematic literature review: Pengembangan media pembelajaran berbasis android untuk meningkatkan kemampuan visual spasial siswa. *Pedagogy: Jurnal Pendidikan Matematika*, 10(4), 2182–2193.
- Shaghaghian, Z., Burte, H., Song, D., & Yan, W. (2024). An augmented reality application and experiment for understanding and learning spatial transformation matrices. *Virtual Reality*, 28(1), 12. <https://doi.org/10.1007/s10055-023-00904-x>
- Amalia, S., Supriadi, S., & Arisetyawan, A. (2025). Problem-Based Learning with Pop-Up Books to Boost Mathematical Critical Thinking in 6th Grade Geometry. *Journal of Innovation and Research in Primary Education*, 4(4), 3682–3698.
<https://doi.org/10.56916/jirpe.v4i4.2471>



- Sri Handayani, Agis Mulya Akbar, & Namira Septia. (2025). Konsep Pendidikan sebagai Suatu Sistem dan Komponen Sistem Pendidikan. *Jurnal Bintang Pendidikan Indonesia*, 3(1), 322–329. <https://doi.org/10.55606/jubpi.v3i1.3606>
- Rahman, M. S. (2025). Eksplorasi Hubungan Augmented Reality Dan Kecemasan Terhadap Penerapan Kecakapan Matematis Pada Pembelajaran Geometri FMIPA Universitas Negeri Makassar. *RADIAN Journal: Research*, 4(2), 59–70. <https://doi.org/10.35706/radian.v4i2.13169>
- Thomas, D. (1976). *Understanding of selected concepts of transformation geometry among elementary and secondary students. The Ohio State University.*
- Uttal, D. H., McKee, K., Simms, N., Hegarty, M., & Newcombe, N. S. (2024). How Can We Best Assess Spatial Skills? Practical and Conceptual Challenges. In *Journal of Intelligence* (Vol. 12, Number 1). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/jintelligence12010008>
- Yang, R., Zhu, Z., Li, Y., Huang, J., Yan, S., Zhou, S., Liu, Z., Li, X., Li, S., Wang, W., Lin, Y., & Zhao, H. (2025). *Visual Spatial Tuning*. <http://arxiv.org/abs/2511.05491>