SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

ANALYSIS OF STUDENTS' PROCEDURAL ERRORS IN SOLVING GEOMETRIC TRANSFORMATION PROBLEMS BASED ON PROCEDURAL FLUENCY

Putri Nazwa [1], Rehana [2], Yarti Melvina Rambe [3], Yesnita Aprilia [4], Budi Halomoan Siregar[5*]
Universitas Negeri Medan, Medan, Indonesia[1,2,3,4,5]
e-mail: putrinazwa12@mhs.unimed.ac.id, rehana@mhs.unimed.ac.id, yartiirambe@mhs.unimed.ac.id, yesnita.4233311024@mhs.unimed.ac.id, budihalomoan@unimed.ac.id

Diterima: *27/04/2026*; Direvisi: *05/05/2026*; Diterbitkan: *09/05/2026*

ABSTRAK

Penelitian ini bertujuan untuk menganalisis kesalahan prosedural siswa dalam menyelesaikan masalah transformasi geometri berdasarkan indikator kelancaran prosedural dari Kilpatrick (2001), yaitu akurasi, efisiensi, dan fleksibilitas. Pendekatan yang digunakan adalah deskriptif kualitatif dengan dukungan data kuantitatif. Subjek penelitian adalah 32 siswa kelas X di salah satu SMA swasta di Medan yang telah mempelajari materi transformasi geometri. Pengumpulan data dilakukan melalui tes esai sebanyak 5 soal yang dianalisis menggunakan rubrik penilaian untuk setiap indikator kelancaran prosedural. Hasil penelitian menunjukkan bahwa rata-rata kemampuan kelancaran prosedural siswa berada pada kategori rendah dengan skor 0,84 dari skala 4,00. Sebanyak 64,29% siswa berada pada kategori sangat rendah, 25% pada kategori rendah, 7,14% pada kategori sedang, dan hanya 3,57% pada kategori tinggi. Indikator fleksibilitas merupakan yang terlemah dengan rata-rata skor 0,39 (sangat rendah), sedangkan akurasi dan efisiensi masing-masing sebesar 0,95 (rendah). Kesalahan dominan pada akurasi meliputi kesalahan konsep dasar (78,6%), substitusi rumus (67,9%), dan operasi aljabar (64,3%). Pada efisiensi, siswa cenderung mengulang langkah (71,4%) dan menggunakan prosedur yang terlalu panjang (67,9%). Pada fleksibilitas, 96,4% siswa hanya menggunakan satu metode penyelesaian dan 89,3% tidak dapat menuliskan matriks transformasi. Temuan ini menunjukkan perlunya pembelajaran yang lebih menekankan pada fleksibilitas prosedural dan memperkuat pemahaman konseptual.

Kata Kunci: *Akurasi; Efisiensi, Fleksibilitas, Kelancaran Prosedural, Transformasi Geometri*

ABSTRACT

This study aims to analyze students' procedural errors in solving geometric transformation problems based on Kilpatrick's (2001) indicators of procedural fluency, which include accuracy, efficiency, and flexibility. The approach used is qualitative descriptive with quantitative data support. The research subjects were 32 tenth-grade students at a private high school in Medan who had studied geometric transformation material. Data collection was conducted through a 5-question essay test analyzed using a scoring rubric for each indicator of procedural fluency. The results showed that the average student procedural fluency ability was in the low category with a score of 0.84 on a 4.00 scale. A total of 64.29% of students were in the very low category, 25% in the low category, 7.14% in the moderate category, and only 3.57% in the high category. The flexibility indicator was the weakest, with an average score of 0.39 (very low), while accuracy and efficiency were 0.95 (low) each. The dominant errors in accuracy included errors in basic concepts (78.6%), formula substitution (67.9%), and algebraic

https://doi.org/10.51878/secondary.v6i3.10625

operations (64.3%). In terms of efficiency, students tended to repeat steps (71.4%) and use overly long procedures (67.9%). Regarding flexibility, 96.4% of students used only one method of solution, and 89.3% were unable to write down the transformation matrix. These findings indicate the need for instruction that places greater emphasis on procedural flexibility and reinforces conceptual understanding.
Keywords: *Accuracy, Efficiency, Flexibility, Geometric Transformation, Procedural Fluency*

INTRODUCTION

Mathematics plays an important role in developing logical, analytical, systematic, and critical thinking skills. In mathematics learning, students are not only expected to obtain correct answers but also to understand and apply mathematical procedures appropriately. One important component in mathematical proficiency is procedural fluency, which refers to students' ability to apply procedures accurately, efficiently, and flexibly in solving mathematical problems.

In classroom practice, procedural fluency is often interpreted merely as the ability to imitate solution steps demonstrated by teachers. As a result, many students can complete routine tasks but experience difficulties when faced with problems requiring procedural adaptation or alternative strategies. This condition indicates that students' procedural understanding is still limited and not yet fully connected to conceptual understanding.

One mathematical topic closely related to procedural fluency is geometric transformation, which includes translation, reflection, rotation, and dilation. This material requires students to master sequential procedures, coordinate operations, and spatial visualization simultaneously (Budiarto, 2015; Darhim & Rasmedi, 2014). Several studies have shown that students frequently experience difficulties in solving geometric transformation problems. Wahid et al. (2021) found procedural errors such as irregular solution steps, computational inaccuracies, and inappropriate use of symbols. Primrose and Masamah (2025) reported that students often failed to apply reflection formulas correctly, while Rifa'i (2025) identified errors at various stages of problem solving based on Newman's procedure. In addition, Junianingsih (2025) and Kandaga et al. (2022) revealed the existence of epistemological obstacles in understanding transformation concepts.

Previous studies generally focused on identifying error types using Newman's framework or learning obstacle analysis. However, these studies have not specifically examined procedural errors through the dimensions of procedural fluency. Consequently, students' difficulties in applying procedures accurately, efficiently, and flexibly have not been comprehensively explored.

The state of the art of previous studies is summarized in Table 1.

Table 1. State of the Art of Previous Studies

Research	Focus of Study	Limitation
Wahid et al. (2021)	Procedural errors in geometric transformation	Did not analyze procedural fluency dimensions
Rifa'i (2025)	Newman error analysis	Focused only on error stages
Primrose & Masamah (2025)	Errors in transformation geometry	Limited to reflection and Newman theory
Kandaga et al. (2022)	Epistemological obstacles	Did not discuss procedural fluency

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

Research	Focus of Study	Limitation
Maifa et al. (2025)	Learning obstacles in geometric transformation	Focused on conceptual and visualization errors

Based on the studies above, it can be seen that research discussing procedural errors in geometric transformations from the perspective of procedural fluency remains limited. Therefore, the novelty of this study lies in analyzing students' procedural errors simultaneously through three indicators of procedural fluency: accuracy, efficiency, and flexibility.

This study aims to analyze students' procedural errors in solving geometric transformation problems based on procedural fluency indicators. The findings are expected to provide a clearer description of students' procedural difficulties and contribute to the improvement of geometry transformation learning.

RESEARCH METHODS

This study employed a descriptive qualitative approach supported by quantitative analysis. The qualitative approach was used to explore and describe students' procedural errors in solving geometric transformation problems, while the quantitative analysis was used to determine students' procedural fluency levels based on scoring results. The study focused on three indicators of procedural fluency: accuracy, efficiency, and flexibility. The research was conducted at a private senior high school in Medan. The participants consisted of 32 tenth-grade students who had studied geometric transformation topics, including translation, reflection, rotation, and dilation. The participants were selected using purposive sampling because the class had completed the transformation geometry material required for the study.

The primary instrument of this study was a procedural fluency test consisting of five essay questions designed to measure students' procedural fluency in geometric transformations. The questions were developed based on three procedural fluency indicators: accuracy, efficiency, and flexibility. In addition, a scoring rubric and validation sheet were used to support data collection and analysis. Before being administered, the instrument was validated through expert judgment involving two mathematics education lecturers and one mathematics teacher. The validation focused on content suitability, clarity of language, appropriateness of transformation concepts, and alignment with procedural fluency indicators. The validation results indicated that the instrument was suitable for use with minor revisions related to wording and question clarity.

Instrument reliability was tested using Cronbach's Alpha coefficient based on students' pilot test results. The reliability coefficient obtained was 0.82, indicating that the instrument had high internal consistency and was appropriate for research purposes.
An example of the test item used in this study is presented below.

Example of Test Item

A triangle with vertices A(2,1), B(4,1), and C(3,3) is reflected across the y-axis and then rotated 90° counterclockwise about the origin. Determine the coordinates of the final image and explain the transformation process used.

The data collection process was conducted through a written test administered during two 40-minute sessions. Students completed the test individually using answer sheets prepared by the researcher. All students' responses were collected and analyzed using a procedural fluency scoring rubric. Data analysis was conducted in two stages: quantitative analysis and qualitative analysis. The quantitative analysis was used to calculate students' procedural

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

fluency scores based on the scoring rubric, while the qualitative analysis was used to identify and describe patterns of procedural errors found in students' responses. The integration of quantitative and qualitative data was intended to provide a more comprehensive understanding of students' procedural fluency profiles.

The scoring rubric for each indicator ranged from 0 to 4, as presented in Table 2.

Table 2. Procedural Fluency Scoring Rubric

Score	Accuracy	Efficiency	Flexibility
4	All procedures and final answers are correct	Steps are efficient without unnecessary repetition	Uses at least two correct solution methods
3	Minor procedural error but final answer is correct	Efficient with one unnecessary step	Uses two methods, but one is less appropriate
2	Incorrect answer due to procedural error	Some repetitive or inefficient steps	Uses only one method
1	Initial procedure is correct but incomplete	Disorganized procedures	Limited flexibility
0	No response or completely incorrect	No efficient procedure	No alternative method

After scoring all responses, students' procedural fluency levels were categorized into five levels: very high, high, moderate, low, and very low. The classification is presented in Table 3.

Table 3. Categories of Procedural Fluency Levels

Category	Score Range
Very High	3.5–4.0
High	2.8–3.4
Moderate	2.0–2.7
Low	1.0–1.9
Very Low	< 1.0

The qualitative analysis was conducted by examining students' written responses to identify patterns of procedural errors related to accuracy, efficiency, and flexibility. Students' answer excerpts were then interpreted descriptively to explain the characteristics of procedural difficulties experienced by students in geometric transformation problems. The research procedure consisted of three stages: (1) preparation stage, including instrument development, expert validation, and pilot testing; (2) data collection stage through written tests; and (3) data analysis stage involving scoring, categorization of procedural fluency levels, identification of procedural errors, interpretation of findings, and report preparation.

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

RESULTS AND DISCUSSION

Result

A total of 32 tenth-grade students participated in this study. However, only 28 students completed all test items, while 4 students submitted incomplete responses or were absent during the test session. Therefore, the analysis was conducted using the responses of 28 students. The descriptive statistics of students' procedural fluency scores are presented in Table 3.

Table 3. Descriptive Statistics of Students' Procedural Fluency

Statistic	Score
Maximum Score	2.93
Minimum Score	0.00
Mean	0.84
Standard Deviation	0.81
Median	0.63
Mode	0.00

The results indicate that students' procedural fluency in solving geometric transformation problems was generally low, with an average score of 0.84 out of 4.00. The relatively high standard deviation (0.81) shows that students' procedural abilities varied considerably. In addition, the mode score of 0.00 indicates that many students failed to demonstrate adequate procedural fluency in several test items.

To identify the distribution of students' procedural fluency levels, the average scores were classified into five categories, as shown in Table 4.

Table 4. Distribution of Procedural Fluency Levels

Category	Score Range	Frequency	Percentage (%)
Very High	3.5–4.0	0	0.00
High	2.8–3.4	1	3.57
Moderate	2.0–2.7	2	7.14
Low	1.0–1.9	7	25.00
Very Low	< 1.0	18	64.29
Total		28	100.00

The findings reveal that most students (64.29%) were categorized in the very low procedural fluency level, while only one student achieved the high category. No students reached the very high category. These findings suggest that students still experience substantial difficulties in applying geometric transformation procedures systematically and correctly.

Further analysis was conducted based on three indicators: *accuracy*, *efficiency*, and *flexibility*. The results are shown in Table 5.

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

Table 5. Average Scores of Procedural Fluency Indicators

Indicator	Average Score	Category
Accuracy	0.95	Low
Efficiency	0.95	Low
Flexibility	0.39	Very Low
Total Average	0.84	Very Low

The *flexibility* indicator obtained the lowest score (0.39), indicating that students had significant difficulty using alternative solution strategies. Meanwhile, *accuracy* and *efficiency* were categorized as low, suggesting that students still made procedural and computational errors even when following standard methods.

The comparison of procedural fluency indicators is illustrated in Figure 1.

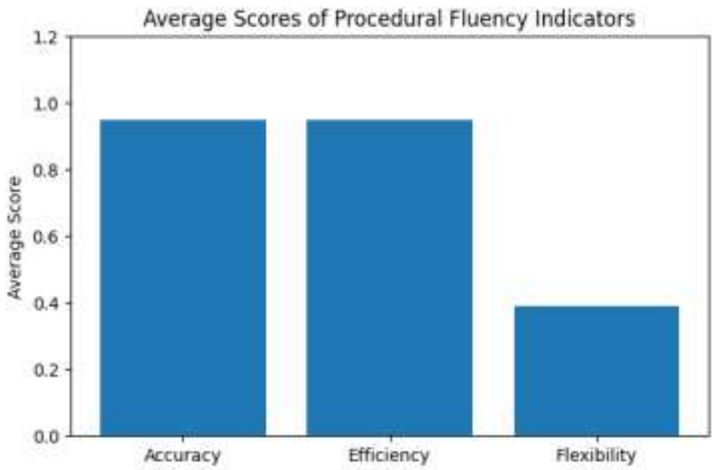

Figure 1. Average Scores of Procedural Fluency Indicators

The figure 1 shows a significant gap between flexibility and the other two indicators. This finding indicates that students tend to rely on a single routine procedure and rarely attempt alternative methods when solving geometric transformation problems.

Qualitative analysis was conducted using a structured coding scheme (Sxx/I/Qx) to identify patterns of procedural errors. The classification of errors is presented in Table 6.

Table 6. Types of Procedural Errors

Indicator	Type of Error	Percentage
Accuracy	Basic conceptual errors	78.6%
	Substitution errors in formulas	67.9%
	Algebraic computation errors	64.3%
	Failure to complete procedures	75.0%
Efficiency	Repetitive unnecessary steps	71.4%
	Redrawing coordinates excessively	60.7%
	Overly complicated procedures	67.9%

https://doi.org/10.51878/secondary.v6i3.10625

Indicator	Type of Error	Percentage
Flexibility	Using only one solution method	96.4%
	Inability to use alternative approaches	92.9%
	Inability to use transformation matrices	89.3%

The results show that errors were most dominant in the *flexibility* indicator. Nearly all students relied on a single method and were unable to apply alternative approaches.

Examples of Procedural Errors Based on Data Coding

Accuracy Error

Student code: **S12/A/Q2**

The student incorrectly substituted coordinates into the rotation formula. Although the initial procedure was correct, the sign of the y-coordinate was changed incorrectly during the transformation process, resulting in an incorrect final answer. This error indicates that the student understood the general procedure but lacked accuracy in applying transformation rules.

Efficiency Error

Student code: **S07/E/Q3**

The student solved the reflection problem by repeatedly drawing coordinate axes and plotting points manually, even though the coordinates could have been calculated directly using transformation rules. As a result, the procedure became unnecessarily long and inefficient.

Flexibility Error

Student code: **S19/F/Q5**

The student solved the dilation problem using only a coordinate substitution method and was unable to provide an alternative approach using transformation matrices. When asked to explain another strategy, the student left the section blank. This finding shows that the student relied solely on one familiar procedure and lacked procedural flexibility.

Overall, the qualitative findings indicate that students' procedural difficulties were not limited to computational inaccuracies but also involved limited procedural adaptability. Students tended to imitate routine procedures and experienced difficulties when problems required alternative strategies or procedural modifications.

Discussion

The findings show that students' procedural fluency in solving geometric transformation problems is still relatively low, with an average score of 0.84 out of 4.00. Most students were categorized in the very low category, indicating that they still experience difficulties in applying transformation procedures accurately, efficiently, and flexibly. These findings suggest that students tend to rely on memorizing procedures rather than understanding the concepts underlying geometric transformations. Geometry transformation material itself requires students to connect symbolic, visual, and algebraic representations simultaneously (Budiarto, 2015; Darhim & Rasmedi, 2014; Nugroho et al., 2018).

Among the three procedural fluency indicators, flexibility was identified as the weakest aspect, with an average score of only 0.39. Most students used only one solution strategy and were unable to provide alternative approaches or representations. This finding indicates that

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

students are not yet accustomed to exploring multiple strategies when solving mathematical problems. Similar findings were reported by Wahid et al. (2021), who found that students frequently experienced procedural irregularities and difficulties in organizing solution steps systematically. Rifa'i (2025) and Primrose and Masamah (2025) also reported that students' errors in geometric transformations were dominated by procedural difficulties and weak understanding of transformation concepts. Likewise, Agustiani (2021) found that students commonly made procedural errors because they failed to interpret problem structures correctly before applying procedures.

The low flexibility found in this study may be related to classroom learning practices that emphasize routine exercises and procedural imitation. Students generally solved problems using procedures demonstrated by the teacher without understanding why those procedures worked. Consequently, students experienced confusion when confronted with problems requiring procedural modification or alternative strategies. This condition is consistent with the findings of Kandaga et al. (2022), who identified epistemological obstacles in transformation geometry, particularly related to students' limited understanding of transformation concepts. Junianingsih (2025) similarly found that students often misunderstood the properties of rotation and reflection because classroom learning tended to focus on procedural completion rather than conceptual reasoning.

In terms of accuracy, students frequently made conceptual and computational errors, particularly in substituting coordinates into transformation formulas and completing procedures correctly. These findings indicate that students' conceptual understanding of geometric transformations remains incomplete. Giovanni et al. (2023) found similar results, where students experienced difficulties constructing systematic procedures when solving transformation problems. Maifa et al. (2025) also reported that students' errors in geometric transformation were closely related to conceptual, procedural, and visualization obstacles. In addition, Napfiah and Sulistyorini (2021) explained that students' misunderstanding of relationships among transformation concepts often leads to repeated procedural mistakes.

The efficiency indicator also showed relatively low performance. Many students used unnecessarily long procedures, repeated calculations, or redrew coordinate systems even when direct procedures could be applied. This finding suggests that students have not yet developed efficient procedural thinking. Similar findings were reported by Maifa (2019), who found that students often performed excessive procedural steps when constructing proofs in transformation geometry. Procedural inefficiency may also indicate that students have not fully internalized mathematical structures and relationships between procedures.

The dominance of flexibility-related errors further indicates weak mathematical connections among concepts. Many students were unable to use transformation matrices or alternative representations in solving problems. This condition reflects fragmented mathematical understanding, where students learn procedures separately without connecting them to broader mathematical structures. Noto et al. (2019) found that preservice mathematics teachers also experienced learning obstacles in proving geometric transformations due to weak conceptual integration. Similarly, Kuncoro et al. (2024) emphasized that understanding geometry requires interconnected procedural and conceptual reasoning rather than isolated procedural practice.

The findings of this study may also be related to the didactical design commonly used in classroom learning. Fitriani and Widjajanti (2024) explained that inappropriate didactical designs can contribute to the emergence of learning obstacles in mathematics. Jatisunda et al.

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

(2025) further emphasized the importance of prospective didactical analysis in anticipating students' procedural difficulties during learning. In addition, Fardian et al. (2025) highlighted that weaknesses in mathematical procedural understanding may originate from systemic and epistemic aspects embedded in instructional materials and classroom practices.

From a broader perspective, mathematics learning should not only emphasize procedural completion but also provide opportunities for students to explore different strategies, construct meaning, and connect multiple representations. In transformation geometry, contextual and exploratory approaches may support students in developing stronger conceptual and procedural understanding. Kusuma et al. (2024) highlighted the importance of contextual mathematical learning approaches in increasing students' engagement and meaning-making processes in mathematics learning.

Overall, the findings indicate that students' procedural fluency in geometric transformations still needs significant improvement, particularly in flexibility and conceptual understanding. Therefore, mathematics learning should provide more opportunities for students to compare procedures, discuss alternative strategies, and justify their reasoning processes. Learning activities involving open-ended problems, reflective discussions, and visualization-based instruction may help students develop deeper procedural understanding and more flexible mathematical thinking. These efforts are important to reduce students' procedural errors and improve their understanding of geometric transformations comprehensively.

CONCLUSION

Based on the analysis results, it is concluded that students' procedural fluency in solving geometric transformation problems falls into the very low category. The majority of students are in the very low category and only a small proportion reached the high category. The main weakness lies in the flexibility indicator, which is far below the accuracy and efficiency indicators. This is evidenced by students' inability to use more than one solution method and their inability to write down the transformation matrix. Regarding the accuracy indicator, dominant errors include errors in basic concepts, failure to complete the procedure to the final result, as well as errors in substitution and algebraic operations. Regarding the efficiency indicator, students tend to repeat unnecessary steps and use overly lengthy procedures. These findings indicate that procedural errors are multidimensional, reflecting weak conceptual understanding, low flexibility of thinking, and the presence of affective barriers. Thus, the hypothesis stating that significant procedural errors exist across all three indicators with flexibility as the primary source of errors is accepted.

Based on the findings of this study, several suggestions are proposed. For mathematics teachers, future learning should be designed to build strong conceptual understanding, train flexibility through the exploration of various strategies, strengthen connections between topics (especially matrices), and familiarize students with proof problems so that they can use procedures accurately, efficiently, and flexibly. For future researchers, it is recommended to conduct intervention studies such as classroom action research or experimental studies that implement problem-based learning or inquiry-based learning models to improve students' procedural fluency, particularly the flexibility indicator.

https://doi.org/10.51878/secondary.v6i3.10625

SECONDARY: Jurnal Inovasi Pendidikan Menengah
Vol. 6, No. 3, Mei-Juli 2026
e-ISSN : 2774-5791 | p-ISSN : 2774-8022
Online Journal System : https://jurnalp4i.com/index.php/secondary

REFERENCE

Agustiani, N. (2021). Analyzing students' errors in solving sequence and series application problems using Newman procedure. *International Journal on Emerging Mathematics Education, 5*(1), 23–32. https://doi.org/10.12928/ijeme.v5i1.17377

Budiarto, M. T. (2015). *Geometri transformasi* (8th ed.). Universitas Negeri Surabaya.

Darhim, D., & Rasmedi, A. (2014). *Geometri transformasi*. Universitas Terbuka.

Fardian, D., Suryadi, D., & Prabawanto, S. (2025). A praxeological analysis of linear equations in Indonesian mathematics textbooks: Focusing on systemic and epistemic aspect. *Journal on Mathematics Education, 16*(1), 225–254. https://doi.org/10.22342/jme.v16i1.pp225-254

Fitriani, N., & Widjajanti, D. B. (2024). Didactical design of learning mathematics in reducing students' learning obstacles. *AIP Conference Proceedings, 2622*, 140010. https://doi.org/10.1063/5.0133555

Giovanni, L. D. A., Parta, I. N., Susanto, H., & Anwar, L. (2023). Analisis kesalahan siswa berbakat matematika dalam memecahkan masalah transformasi geometri berdasarkan langkah Polya. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 12*(1), 1039–1049. https://doi.org/10.24127/ajpm.v12i1.6653

Jatisunda, M. G., Suryadi, D., Prabawanto, S., & Umbara, U. (2025). Pre-service mathematics teacher conducting prospective analysis: A case study on practice didactical design research. *Infinity Journal, 14*(1), 21–44. https://doi.org/10.22460/infinity.v14i1.p21-44

Junianingsih, Y. (2025). *Desain learning trajectory dengan konteks batik singa barong pada materi transformasi geometri untuk mengatasi learning obstacle siswa* [Thesis, UIN SSC]. https://repository.syekhnurjati.ac.id/16705/

Kandaga, T., Rosjanuardi, R., & Juandi, D. (2022). Epistemological obstacle in transformation geometry based on van Hiele's level. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(4), em2096. https://doi.org/10.29333/ejmste/11914

Kuncoro, K. S., Suryadi, D., Dahlan, J. A., & Jupri, A. (2024). Praxeological analysis in Indonesian and Singaporean mathematics textbooks: An understanding geometrical similarity by students. *Journal on Mathematics Education, 15*(4), 1197–1218. https://doi.org/10.22342/jme.v15i4.pp1197-1218

Kusuma, A. B., Hanum, F., Abadi, A. M., & Ahmad, A. (2024). Exploration of ethnomathematics research in Indonesia 2010–2023. *Infinity Journal, 13*(2), 393–412. https://doi.org/10.22460/infinity.v13i2.p393-412

Maifa, T. S. (2019). Analisis kesalahan mahasiswa dalam pembuktian transformasi geometri. *Jurnal Riset Pendidikan dan Inovasi Pembelajaran Matematika, 3*(1), 8–14. https://doi.org/10.26740/jrpipm.v3n1.p8-14

Maifa, T. S., Suryadi, D., & Fatimah, S. (2025). Identifying learning obstacles in proof construction for geometric transformations: Conceptual, procedural, and visualization errors. *Infinity Journal, 14*(3), 673–694. https://doi.org/10.22460/infinity.v14i3.p673-694

Napfiah, S., & Sulistyorini, Y. (2021). Errors analysis in understanding transformation geometry through concept mapping. *International Journal of Research in Education, 1*(1), 6–15. https://doi.org/10.26877/ijre.v1i1.5863

Noto, M. S., Priatna, N., & Dahlan, J. A. (2019). Mathematical proof: The learning obstacles of preservice mathematics teachers on transformation geometry. *Journal on*

Mathematics Education, 10(1), 117–126. https://doi.org/10.22342/jme.10.1.5379.117-126

Nugroho, A. A., Rahmawati, N. D., & Kartinah, K. (2018). *Geometri transformasi*. UPGRS Press.

Primrose, A. T., & Masamah, U. (2025). Kesalahan siswa dalam menyelesaikan soal transformasi geometri pada etnomatematika batik kawung berdasarkan teori Newman. *11*(1), 1–12. https://doi.org/10.52657/je.v11i1.2692

Rifa'i, A. (2025). *Analisis kesalahan menyelesaikan soal matematika materi transformasi geometri berdasarkan prosedur Newman pada siswa kelas IX MTs Muhammadiyah Al Furqan Banjarmasin* [Thesis, UIN Antasari Banjarmasin]. https://idr.uin-antasari.ac.id/28364/

Surya, F., & Edriati, S. (2024). Analysis of students' error in working on story problems based on Newman's criteria in class II MIA 3 MAN 3 Padang. *Al Khawarizmi: Jurnal Pendidikan dan Pembelajaran Matematika, 7*(2), 74. https://doi.org/10.22373/jppm.v7i2.19744

Takaendengan, B. R., Anwar, A., Takaendengan, W., & Kobandaha, P. E. (2022). Identifikasi kesalahan jawaban mahasiswa pada mata kuliah analisis real berdasarkan Newman's error analysis. *Euler: Jurnal Ilmiah Matematika, Sains dan Teknologi, 10*(2), 235–243. https://doi.org/10.34312/euler.v10i2.16777

Wahid, A., Ayuningtyas, D., Wahyuningsih, E. D., & Paridjo. (2021). Analisis kesalahan siswa secara prosedural dalam menyelesaikan soal transformasi geometri. *JIPMat, 6*(1), 24–33. https://doi.org/10.26877/jipmat.v6i1.8125

https://doi.org/10.51878/secondary.v6i3.10625