

# Analysis Of Students' Errors In Solving Geometric Transformation Problems At Sma Amir Hamzah Medan

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## ABSTRACT

This study aims to analyze the types of errors made by 11th grade students at SMAS Amir Hamzah Medan in solving geometric transformation problems involving translation, reflection, rotation, and dilation. The study employs a qualitative descriptive approach with a sample of 15 students selected based on high, medium, and low ability categories. Data were collected through essay tests and analyzed using Newman's Error Analysis, which consists of five stages of errors: reading, understanding, transformation, process skills, and writing the final answer. The analysis results indicate that the highest incidence of errors occurred in the understanding stage and process skills stage, each accounting for 36%. Transformation errors accounted for 21.33%, while reading and final answer writing errors were in the very low category, each at 9.33%. These findings indicate that students still face difficulties in understanding basic concepts and technical steps in geometric transformations. Based on these results, it is recommended that teachers implement systematic learning strategies such as Learning Therapy, emphasizing the understanding of prerequisite concepts, writing down known and asked information, and developing the habit of structuring and evaluating solution steps systematically to minimize similar errors in the future.

**Keywords:** Geometric Transformation, Error Analysis, Newman Procedure



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## INTRODUCTION

Mathematics is a science that utilizes logic to study the structure, shape, quantity, and relationships between interrelated concepts. The ability to understand something is crucial in human life, and with this understanding, humans are required to possess the ability to comprehend (Tahir & Marniati, 2022). Among the many topics taught at the high school level, geometric transformations are one of the most challenging topics for students. (Ilmiyah et al., 2018).

Geometric transformation is a branch of mathematics that studies changes in the position, size, or orientation of a geometric object without changing its intrinsic characteristics. This concept involves moving a point, line, or plane from one location to another in Euclidean space. In general, a geometric transformation can be understood as a bijective function from a set of points to itself, which preserves certain geometric properties such as distances or angles (Djamiluddin & Wardana, 2019).

Geometric transformations are a branch of geometry that encompasses transformations (changes), both in position and in representations based on images and metrics. Types of transformations include translation, rotation, reflection, and dilation. Each type of transformation has unique characteristics and different rules for changing the position or size of an object (Grant-Smith & Colley, 2018).

Translation, or shift, is a geometric transformation that moves every point on an object the same distance and in the same direction (Smith et al., 2018). In translation, an object changes position without changing its shape, size, or orientation. This means that all parts of the object move uniformly along a certain shift vector (Sari et al., 2017). Translation can be thought of as moving an object from one place to another on a plane. If a point  $P(x, y)$  is shifted by a distance of 'a' units horizontally and 'b' units vertically, then its new position  $P'(x', y')$  will be  $(x+a, y+b)$ . This vector  $(a, b)$  determines the direction and magnitude of the shift.

Reflection is moving a geometric shape or object with a distance that has the same value between the point of displacement with the mirror and the starting point with the mirror (Halim & Rasidah, 2019). The reflected object will produce an image of the object caused by a mirror (Miao et al., 2018). The reflection result depends on the axis that becomes the mirror in the Cartesian plane. All points that experience reflection will be moved by using the reflection properties of a plane mirror (Dickinson et al., 2019). The resulting transformation is congruent with the transformed building. Reflection is included in the opposite isometric transformation (Magfirah et al., 2019).

Rotation is a transformation that pairs a point to another set of points by rotating or in other words rotation is the event of moving an object (image) through a curved line with the center at a certain point and with a certain rotation angle in a clockwise or counterclockwise direction which causes the position of the image to change. A rotation is said to have a positive direction if the rotation is opposite to the direction of the clockwise rotation and the rotation is said to be negative if the rotation is in the same direction as the clockwise rotation (Vitaloka et al., 2020).

Dilation can be determined by the center point and the dilation factor (scale factor). Dilation is a transformation that changes the size of a shape (enlargement or multiplication or reduction or enlargement) with the shape of the shape remaining unchanged, remaining as before. In dilation, the object is enlarged or reduced from a fixed point called the center of dilation, with a certain scale factor (Kalengkongan et al., 2021). Dilation involves changing the size of the object based on the scale factor ( $k$ ) and the center of dilation. If  $k > 1$ , the object is enlarged; if  $0 < k < 1$ , the object is reduced. If  $k$  is negative, the object will also experience a 180-degree rotation (Seng, 2020).

In practice, particularly at Amir Hamzah Senior High School in Medan, not all students are able to understand and apply the concept of transformation well. Students' difficulties in solving geometric transformation problems are often influenced by misunderstandings of basic concepts, operational procedures, and coordinate calculations. Conceptual understanding is a crucial aspect in mathematics learning, going beyond simply memorizing formulas or procedures. It involves students' ability to understand the meaning, properties, and relationships between mathematical concepts, and to apply them in various situations. Conceptual understanding is the result of a person's thinking and ability to develop abstract ideas and group objects according to their characteristics. (Utami et al., 2024). A strong conceptual understanding is the foundation for developing higher-order thinking and problem-solving skills (Sumule et al., 2018).

Several previous studies have shown that geometric transformations, particularly rotations and dilations, are a subtopic that frequently leads to errors in student problem-solving. Wasilah et al. (Lestari & Afriansyah, 2022) found that students experience difficulties in understanding basic transformation concepts, such as the correct use of formulas, matrix operations, and determining the direction and center of rotation. These errors often stem from inactive learning methods, dependence on teachers, and a lack of understanding of the transformation concept itself. Furthermore, Newman's error analysis approach identified that students also frequently experience difficulties in transforming problem information into mathematical models, performing calculation steps, and writing answers in correct notation (Pulungan, 2022). These errors indicate that many students lack the comprehensive skills to solve geometric transformation problems systematically and conceptually (Ayuwirdayana, 2019).

Based on the explanation above, this study focuses on analyzing errors made by eleventh-grade students of SMAS Amir Hamzah Medan in solving geometric transformation problems. Hutagalung (2017) also confirmed that the reality in the field shows that students' understanding of mathematical concepts is relatively low. The results of this analysis are expected to be a reference for further research, as well as a guide for teachers in developing learning strategies to improve students' understanding of geometric transformation material.

## METHOD

This study uses a qualitative descriptive approach that focuses on describing students' errors in working on geometric transformation problems without numerical intervention or inferential statistics. This approach is oriented towards natural and contextual phenomena. According to (Ly & Takuya, 2023), qualitative research is an approach to conducting research that is oriented towards natural phenomena or symptoms. Qualitative research is fundamental and naturalistic in nature, and cannot be conducted in the laboratory, but rather in the field. This allows researchers to explore the meaning and patterns of errors based on real data, as emphasized (Pangaribuan et al., 2024), that this approach does not require many participants or rigid planning, but is flexible enough to explore unique information (Widjajanti, 2024).

The research subjects were eleventh-grade students at Amir Hamzah High School, Medan, who were selected using purposive sampling to represent three ability categories (high, medium, low) based on the pretest results. The research instruments consisted of: (1) pretest questions on geometric transformations, (2) learning sessions on geometric transformations (translation, rotation, reflection, and dilation), and (3) equivalent posttest questions to observe changes and patterns of student errors after learning (Cholissodin et al., 2023).

Data analysis was conducted using Newman Error Analysis, which covers five stages of errors: reading, comprehension, transformation, process skills, and encoding. This technique is used to systematically identify students' thinking barriers in solving math problems<sup>3</sup>. Next, the data was manually analyzed by calculating the frequency of each error category, then calculating the percentage using the following formula: (Rahmawati & Permata, 2018) :

$$P = \frac{n}{N} \times 100\%$$

Information:

P = Percentage of student error types

n = Number of errors for each stage

N = Number of possible errors

The results of the percentage calculations were then converted into qualitative data and interpreted as conclusions for each category of error made by students in solving geometric transformation problems (Flaviani & Carballosa, 2023b). These error level categories refer to the following percentage conversion guidelines from Widoyoko (Fitriatien, 2019) :

**Table 1. Guidelines for Converting Percentages to Categories**

Percentage (%)	Category
$P > 80$	Very high
$60 < P \leq 80$	Tall
$40 < P \leq 60$	Currently
$20 < P \leq 40$	Low
$P \leq 20$	Very Low

## RESULTS AND DISCUSSION

### Results

The study, conducted on 15 eleventh-grade students at Amir Hamzah High School in Medan, presented a test in either essay format or geometry format. Five questions were given, and the time allocated was 60 minutes. The following is a sample of the questions, as seen in Figure 1.

**TES SOAL**

Sekolah : SMA Amir Hamzah

Nama Siswa :

Kelas :

Petunjuk soal :

- Berdoa sebelum mengerjakan soal
- Tuliskan nama dan kelas pada bagian yang sudah disediakan!
- Selesaikan terlebih dahulu soal yang menurut anda mudah
- Tidak diperkenankan bekerja sama
- Sebelum di kumpulkan harap periksa kembali hasil jawaban anda

Soal

1. Tentukan hasil bayangan titik  $A(3,5)$  oleh transisi  $T\begin{pmatrix} -2 \\ 4 \end{pmatrix}$
2. Diketahui titik  $P(4, -12)$  adalah bayangan titik P oleh translasi  $T\begin{pmatrix} -9 \\ 8 \end{pmatrix}$ . Koordinat titik P adalah
3. Titik  $P(5, -4)$  dicerminkan terhadap garis  $y = x$ . koordinat bayangan titik P adalah
4. Sebuah segitiga dengan titik-titik sudut  $A(1,1)$ ,  $B(3,1)$ , dan  $C(2,4)$  didilatasi dengan pusat di titik  $(0,0)$  dan factor skala  $k = 0,5$ . Tentukan koordinat bayangan segitiga tersebut.
5. Tentukan koordinat bayangan hasil rotasi titik  $A(3,4)$  sebesar  $90^\circ$  terhadap titik pusat  $O(0,0)$ .

**Figure 1. Test Questions**

Based on the test results of class XI students of Amir High School after working on the test questions as in **Figure 1**, the following is the percentage of errors made by students according to the stages of *Newman's error* (Habibah et al., 2020) :

**Table 2. Percentage of Errors based on Newman's Stages**

<i>Error Form</i>	<i>Many Students Make Amount</i>					<i>Percentage</i>	<i>Interpretation</i>	
	<i>Mistakes in the Questions</i>							
	1	2	3	4	5			
<i>Read</i>	0	0	1	2	6	7	9.33%	Very low
<i>Understand</i>	2	6	2	6	11	27	36.00%	Low
<i>Transformation</i>	0	6	2	4	4	16	21.33%	Low
<i>Process expertise</i>	2	6	2	11	6	27	36.00%	Low
<i>Final Answer Assessment</i>	0	0	1	1	5	7	9.33%	Very Low

Based on an analysis of errors made by eleventh-grade students at Amir High School using Newman's stages, it was found that the most common errors occurred in the Understanding Questions and Process Skills stages, reaching 36% each. This indicates that many students have difficulty understanding the meaning of questions and applying mathematical steps correctly (Wahyuningsih et al., 2020).

Errors in the Transformation stage were recorded at 21.33%, indicating that students were less able to convert information from the problem into mathematical form. Meanwhile, errors in the Reading, Assessment, and Final Answer stages each reached 9.33%. These findings emphasize the importance of strengthening conceptual understanding and skills in solving problems in a structured manner during the mathematics learning process.

## Discussion

According to the information obtained, there are various types of errors made by students when solving geometric mathematics problems involving translation. These errors will be explained in more detail using Newman's procedure as follows.

Reading error : A stage where students misunderstand key words or symbols in a problem, preventing them from proceeding to the correct solution, or where students fail to read the question and record the information contained in it. Examples of errors include the following:

Figure 2. Reading error

From Figure 2, students seem to have misread the problem, especially in the part “reflected against the line  $y=x$ ”. This can be seen from the fact that students use an approach or reflection formula that is not appropriate for the line (for example, reflecting against another axis or line) (Apriandi et al., 2020). The initial indication by writing the reflection as  $(-8,9)$  shows that the information from the problem was not processed correctly from the start. (Velria Jun et al., 2022).

Comprehension *Misunderstandings* occur when students fail to understand the intent or context of a problem even though they have read it correctly. In other words, students are able to read the words in the problem, but do not understand the relationships between the information or do not know what to look for/ask in the problem. Examples of student errors include the following (Flaviani & Carballosa, 2023a):

Figure 3. Misunderstanding

In question number 2, the student misunderstood the role of point  $P'$ . He considered point  $P'$  as the origin point that would be reflected, whereas  $P'$  was the result of the reflection of  $P$  against point  $T$ . Because he misunderstood the structure of the relationship between the origin and the image, the student chose the wrong step, namely subtracting point  $P'$  from  $T$ , instead of composing the reflection equation from the point to the center. Although the student's answer was correct, the student misunderstood the question (Simamora & Saragih, 2019).

Transformation *errors* occur when students have difficulty converting data from a problem into a mathematical model or method appropriate for solving it. In this case, students understand what is being asked, but they are confused or mistaken about which mathematical operation to apply (Haq et al., 2022). This is an example of the student error below.

Figure 4. Transformation Error

The student's main error in question 5 lies in the transformation stage. Although the student understands the purpose of the problem, which is to rotate  $90^\circ$  about the origin, he is unable to convert this information into the correct mathematical steps. The student appears to be unaware of or has forgotten the rotation formula  $(x,y) \rightarrow (-y,x)$  and is therefore unable to continue the solution (Cai & Leikin, 2020). This indicates that the student has difficulty connecting the concept of rotation with mathematical procedures, which is a characteristic of transformation errors in the Newman Procedure (Ashidiq & Masduki, 2019).

The next error is a process skill error, where students have difficulty carrying out the technical steps of the solution, even though they may understand the basic concepts used. In this context, the student incorrectly wrote down the steps for matrix multiplication, even though the final result was correct. In the problem of a  $90^\circ$  rotation about point  $(3,4)$ , the student should have used a rotation matrix (Prayitno et al., 2022).

The image shows handwritten work on grid paper. At the top, the student writes:  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos 90^\circ & -\sin 90^\circ \\ \sin 90^\circ & \cos 90^\circ \end{pmatrix} \begin{pmatrix} 3 \\ 4 \end{pmatrix}$ . Below this, they write a matrix multiplication:  $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} 3 \\ 4 \end{pmatrix}$ . Then, they show two rows of calculations:  $\begin{pmatrix} 0 & + & -4 \\ 3 & + & 0 \end{pmatrix} = \begin{pmatrix} -4 \\ 3 \end{pmatrix}$ . This leads to  $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} -4 \\ 3 \end{pmatrix}$ , and finally  $x' = -4$ ,  $y' = 3$ , and the point  $A'(-4, 3)$ .

**Figure 5. Process Skills Errors**

However, in Figure 5, the student wrote the matrix structure incorrectly, making the calculation steps appear confusing. This error indicates a lack of skill in the technical procedure, even though the student understands the concept correctly. Based on the conversion guidelines, this error is classified as Moderate.

Final answer writing error (encoding error). The analysis of the final answer stage found several errors, one of which is seen in Figure 6 regarding the calculation of the transformation of point C  $(2,4)$ . After performing a dilation with a scale of  $\frac{1}{2}$ , the result was obtained  $\left(\frac{2}{2}, \frac{4}{2}\right)$ , but the answer was not simplified to  $(1,2)$  as it should have been.

The image shows handwritten work on grid paper. It shows three points being dilated by a scale of  $\frac{1}{2}$ :  
 $A(1,1) = \frac{1}{2} \rightarrow A'(\frac{1}{2}, \frac{1}{2})$   
 $B(3,1) = \frac{1}{2} \rightarrow B'(\frac{3}{2}, \frac{1}{2})$   
 $C(2,4) = \frac{1}{2} \rightarrow C'(\frac{2}{2}, \frac{4}{2})$

**Figure 6. Final Answer Writing Error**

This indicates that the calculation process is correct, but the final answer is incomplete (TJ Newman, 2020). Furthermore, there are inconsistencies in the formatting of the transformed coordinates, such as the use of brackets and commas that are not neat or consistent across points. These types of errors, although seemingly minor, can affect the clarity and accuracy of mathematical information delivery (Hariyani & Aldita, 2020).

Based on the error analysis found, it can be concluded that one of the main causes of student errors in solving geometric transformation problems is a weak understanding of the basic concepts required as prerequisites (NF Newman & Trautman, 2021). This is evident from the high percentage of errors in the problem understanding and process skills stages according to Newman's analysis (Anderson-Butcher et al., 2019). This indicates the need for strengthening conceptual understanding and training in systematic solution steps. (Maulana, 2020).

By identifying errors based on Newman's Error Analysis, teachers can use these findings as a reference in designing more effective learning strategies. One approach that can be applied to minimize student errors is the application of *Learning Therapy* as conveyed by Junaedi, et al. (Allam & Newman, 2018) . This approach includes five main steps: (1) understanding the prerequisite material completely, (2) getting used to writing down the information known and asked from the problem, (3) writing down the strategy or formula before starting the calculation, (4) solving the problem carefully based on the strategy, and (5) (Stylianou, 2011) rechecking the results of the work and drawing conclusions from the answers (Fantus & Newman, 2021) . By getting students used to following a systematic flow of thought like this, it is hoped that their ability to solve geometric transformation problems will improve and the same errors can be minimized in the next opportunity

## CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that grade XI students of SMA Amir Hamzah Medan still make many errors in solving geometric transformation problems. The most frequent errors occur in the stages of understanding the problem and process skills with a percentage of 36%, indicating that most students are not fully able to understand the content and intent of the problem and have difficulty in applying the steps to solve it correctly. In addition, errors are also often found in the transformation stage with a percentage of 21.33%, where students are less precise in converting problem information into an appropriate mathematical model. Meanwhile, errors in the reading and writing stages of the final answer each have a percentage of 9.33%, which although relatively low, still requires attention so that it does not become a recurring habit. These results indicate that the understanding of the concept of geometric transformation, especially in the material of rotation and dilation, still needs to be improved so that students can solve problems more carefully, systematically, and accurately.

Given these results, it is recommended that teachers implement more varied and interactive learning methods, such as the use of technology-based media that allows students to directly visualize each step of the transformation. Furthermore, it is important for teachers to provide structured and gradual practice problems, ranging from low to high difficulty levels, so that students become accustomed to understanding concepts and procedures systematically. Teachers are also expected to get students used to writing down known and asked information completely before starting calculations, and encourage students to double-check their work before submitting it. The implementation of systematic learning strategies such as these is expected to help students reduce errors, improve conceptual understanding, and develop more organized thinking patterns in solving geometric transformation problems in the future.

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