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AN ANALYSIS OF EIGHTH-GRADE STUDENTS' ERRORS IN SOLVING PYTHAGOREAN THEOREM PROBLEMS BASED ON NEWMAN'S ERROR ANALYSIS

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ABSTRACT

This study aims to describe students' errors in solving Pythagorean theorem problems based on Newman's Error Analysis (NEA). This study employed a qualitative descriptive approach. The subjects consisted of two eighth-grade students of SMP Negeri 1 Banawa Tengah selected through written tests and interviews. The results show that both students made errors at several stages of NEA, with one student committing more errors than the other. The dominant errors occurred at the comprehension, transformation, and process skill stages. These errors were caused by limited conceptual understanding of the Pythagorean theorem, carelessness in calculations, and haste in answering the questions. The findings of this study provide insights for improving mathematics instruction, particularly in strengthening students' conceptual understanding and problem-solving skills.

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1. INTRODUCTION

Mathematics is one of the subjects that plays a crucial role in developing students' logical, analytical, and systematic thinking skills. Through mathematics learning, students are trained to understand concepts, construct logical arguments, and solve problems in a structured manner. Therefore, mathematics is not only essential in academic contexts but also highly relevant to everyday life and the advancement of science and technology.

Mathematics education at the basic and secondary levels is expected to equip students with the thinking skills necessary to address various real-life problems effectively (Hayati & Jannah, 2024).

One of the mathematics topics taught at the junior high school level that has strong relevance to daily life is the Pythagorean theorem. This theorem explains the relationship among the sides of a right-angled triangle and is widely applied in various fields, such as construction planning, distance measurement, land mapping, and height calculation. Mastery of the Pythagorean theorem is not only important for students' success in mathematics learning but also supports their ability to solve contextual problems encountered in real-world situations (Marwanto, 2020; Siswiandini, 2023).

Despite being a fundamental topic that is systematically introduced in school mathematics curricula, many students still experience difficulties in understanding and applying the Pythagorean theorem. Preliminary observations conducted at SMP Negeri 1 Banawa Tengah indicate that eighth-grade students frequently make errors in determining the sides of right-angled triangles, particularly in identifying the hypotenuse. In addition, students tend to struggle when the orientation or shape of the triangle differs from the commonly presented form. Another issue observed is students' inability to connect the concept of the Pythagorean theorem with contextual or real-life situations presented in word problems. These findings suggest that students' conceptual understanding of the Pythagorean theorem remains insufficient.

The errors made by students in solving Pythagorean theorem problems may be attributed to several factors. These include weak understanding of basic concepts, incorrect application of formulas, lack of accuracy in calculations, and difficulties in reading and interpreting mathematical problems. Nurwahid (2021) emphasizes that low conceptual understanding and students' carelessness during the problem-solving process are major contributors to errors in mathematics learning. If such errors are not identified and analyzed systematically, students are likely to repeat the same mistakes when dealing with similar mathematical topics in the future.

Therefore, a systematic analysis is required to identify the types of errors students make when solving Pythagorean theorem problems. One widely used procedure for analyzing students' errors in mathematics education research is Newman's Error Analysis (NEA). Developed by Anne Newman in 1977, this procedure is designed to identify students' errors based on the stages of thinking involved in solving mathematical word problems. Newman classified students' errors into five stages: reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors.

Error analysis using Newman's Error Analysis enables researchers to obtain a more detailed understanding of where and why students' errors occur during the problem-solving process. By identifying errors at each stage, teachers and researchers can determine whether students' difficulties arise from misunderstanding the problem, incorrectly transforming the problem into mathematical expressions, performing inaccurate calculations, or failing to present correct final answers. Although several previous studies have examined students' difficulties in learning the Pythagorean theorem, research that specifically analyzes students' errors using Newman's Error Analysis at the junior high school level remains limited. In particular, studies conducted in the context of SMP Negeri 1 Banawa Tengah are still scarce, indicating the existence of a research gap that needs to be addressed.

Based on the above considerations, this study focuses on analyzing students' errors in solving Pythagorean theorem problems using Newman's Error Analysis. The purpose of this study is to describe the types of errors made by eighth-grade students of SMP Negeri 1 Banawa Tengah when solving problems related to the Pythagorean theorem based on Newman's error stages. The findings of this study are expected to contribute to the improvement of mathematics instruction by providing teachers with a deeper understanding of students' errors, enabling them to design more effective and targeted learning strategies. Furthermore, this study is expected to serve as a reference for future research on students' error analysis in mathematics learning, particularly in relation to the Pythagorean theorem.

2. METHOD

This study adopts a qualitative descriptive approach to explore in depth students' errors in solving Pythagorean theorem problems based on Newman's Error Analysis.

This study was conducted at SMP Negeri 1 Banawa Tengah, located in Banawa Tengah District, Donggala Regency, Central Sulawesi, during the 2025/2026 academic year. The research subjects consisted of two eighth-grade students selected through purposive sampling. The subjects were selected using purposive sampling based on the following criteria: (1) students who answered all test items, (2) students who made the most errors, (3) students willing to participate in interviews, and (4) teacher recommendations.

The instruments used in this study consist of the main instrument and supporting instruments. In this qualitative study, the researcher served as the primary research instrument.

1. The written test consisted of one essay question on the Pythagorean theorem, which was reviewed and validated by mathematics education experts prior to data collection.

> Andi runs around a rectangular field. From the starting point, he runs along one side of the field for 50 m, then turns and runs along the other side for 120 m. Andi wants to return to the starting point. What is the shortest distance he must travel to return to the starting point?

Figure 1. Written Test on the Pythagorean Theorem Problem

2. An interview guideline was developed by the researcher and validated by experts in mathematics education.

Data were collected through two procedures, namely:

1. A test aimed at identifying where students make mistakes in solving word problems related to the Pythagorean theorem.
2. An interview aimed at clarifying information previously obtained from the students' written test responses. The interview was also conducted to confirm the specific errors made by the students when solving problems in the written test.

The data analysis in this study follows the framework of Miles et al. (2014), encompassing three stages: data condensation, data display, and conclusion drawing. To guarantee the credibility of the findings, a member check procedure was employed, ensuring that the information collected and subsequently reported accurately reflects the perspectives and intentions of the data sources or informants.

3. RESULTS AND DISCUSSION

3.1. Results

This study aimed to identify the types of errors made by eighth-grade students of class VIII A at SMP Negeri 1 Banawa Tengah in solving Pythagorean theorem problems based on Newman's Error Analysis (NEA). Data were obtained through a written test administered to 17 students and follow-up interviews with two selected subjects.

Based on the students' written test results and recommendations from the mathematics teacher, two students—coded as FA and GN—were selected as research subjects using purposive sampling. The selection criteria included students who completed the test, exhibited the most errors, and were willing to participate in interviews.

The students' errors were classified into five stages according to Newman's Error Analysis: reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors. The distribution of errors for each subject is presented in Table 1.

Table 1. Types of Student Errors Based on Newman's Error Analysis

Subject	Reading Error	Comprehension Error	Transformation Error	Process Skill Error	Encoding Error
FA	✓	✓	✓	–	✓
GN	–	–	✓	✓	✓

Table 1 shows that subject FA made errors at four stages of the NEA framework, namely reading, comprehension, transformation, and encoding. In contrast, subject GN made errors at three stages, including transformation, process skill, and encoding errors.

Reading Error

At the reading stage, subject FA demonstrated difficulty in interpreting symbols and terminology used in the problem, particularly the unit of measurement. The following excerpt from the interview illustrates this issue.

Table 2. Interview with Subject FA Related to Reading Error

PN-05	:	Okay, please read the question again.
FA-06	:	Andi runs around a rectangular field. From the starting point, he runs along one side of the field for 50 m, then turns and runs along the other side for 120 m. Andi wants to return to the starting point. What is the shortest distance he must travel to return to the starting point?
PN-07		Earlier, you read 50 m and also 120 m. Do you know what 'm' means?
FA-08		Yes, I know. It's centimeters, right?
PN-15		Okay, that means you understand the given information in this problem. Next, what information is being asked in the problem?
FA-16		What is being asked is the shortest distance Andi must travel to return to his starting point. This means that he goes around the field to return to his original position.

At the reading stage, Subject GN was able to read and interpret all symbols and keywords accurately and did not exhibit reading errors. The following excerpt from the interview illustrates this issue.

Table 3. Interview Responses of Subject GN at the Reading Stage

PN-05	:	Okay, please try to read the question again
GN-06	:	Andi runs around a rectangular field. From the starting point, he runs along one side of the field for 50 meters, then turns and runs along the other side for 120 meters. Andi wants to return to the starting point. What is the shortest distance he must travel to return to the starting point?

PN-13	:	Next, what do you understand from the term ‘shortest distance?
GN-14	:	The shortest distance refers to the shortest path that Andi takes to return to the starting point as quickly as possible.

Comprehension Error

At the comprehension stage, subject FA was able to identify the given numerical information but failed to correctly interpret the key phrase “shortest distance,” which led to an incorrect understanding of the problem’s objective. The following are the results of the written test and interview excerpts related to this matter.

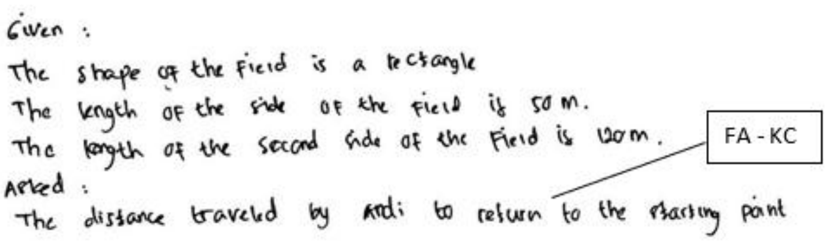

Figure 2. The results of subject FA written test related to Comprehension Error

Table 4. Interview with Subject FA Related to Comprehension Error

PN-13	:	Do you know what information is given and what information is asked in this problem?
FA-14	:	Yes, I know. Andi runs around a rectangular field as shown in my drawing (showing the picture on the answer sheet). The lengths of the sides of the field are 50 m and 120 m (while pointing to the answer sheet).
PN-15		Okay, that means you understand the information given in this problem. Next, what information is being asked?
FA-16		What is being asked is the distance Andi travels to return to his starting point. This means that he goes around the field in order to return to his original position.

At the comprehension stage, subject GN showed a complete understanding of both the given information and what was being asked and therefore did not experience comprehension errors. The following are the results of the written test and interview excerpts related to this matter.

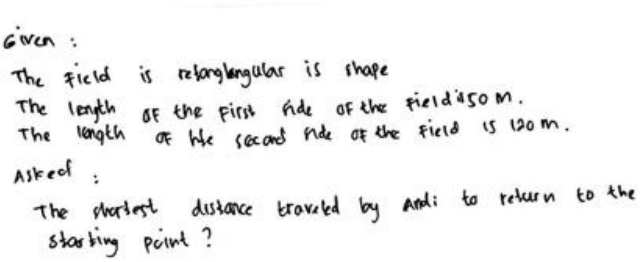

Figure 3. The results of subject GN written test related to Comprehension Error

Table 5. Interview Responses of Subject GN at the Comprehension Stage

PN-07	:	Okay, next, what information did you obtain from the problem you just read?
GN-08	:	What information is given in this problem?
PN-09	:	Yes. Do you know what information is given and what information is being asked?
GN-10	:	Yes, I know. Andi runs around a rectangular field, and the lengths of the sides he runs along are 50 meters and 120 meters.
PN-11	:	So, what is being asked in this problem?
GN-12	:	This is the shortest distance (while pointing to the answer sheet). From the starting point, he only traveled along two sides. If he wants to return to the starting point, the shortest distance would be by cutting across the middle of the field (while pointing to the diagonal of the rectangle in the drawing on the answer sheet)
PN-13	:	Oh, I see. Next, what do you understand by the term 'shortest distance'?
GN-14	:	The shortest distance refers to the shortest path that Andi takes to return to the starting point as quickly as possible.

Transformation Error

At the transformation stage, Subject FA incorrectly selected the perimeter formula of a rectangle instead of applying the Pythagorean theorem. The following are the results of the written test and interview excerpts related to this matter.

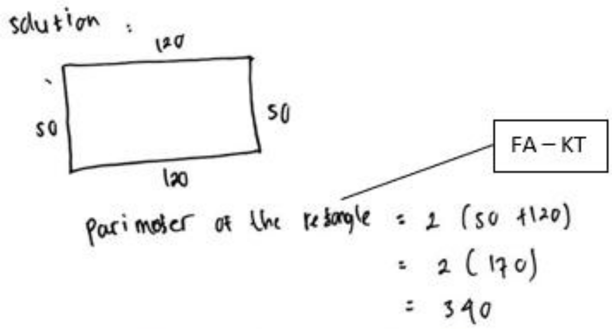

Figure 4. The results of subject FA written test related to Transformation Error

Table 6. Interview with Subject FA Related to Transformation Error

PN-21	:	So, what formula did you use to calculate the distance Andi traveled?
FA-22	:	I used the rectangle perimeter formula. I added the two given sides and then multiplied by two (while pointing to the answer sheet: (50 + 120) × 2 = 340).

At the transformation stage, subject GN was unable to construct an appropriate mathematical model due to forgetting the relevant formula. The following are the results of the written test and interview excerpts related to this matter

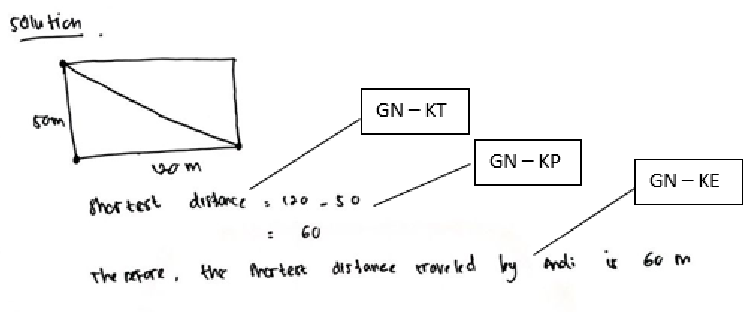

Figure 5. The results of subject GN written test related to Transformation Error

Table 7. Interview with Subject GN Related to Transformation Error

PN-15	:	Oh yes, that's right, but why didn't you continue solving the problem?
GN-16	:	Actually, I know this is a right-angled triangle, so I should use the Pythagorean theorem. However, I forgot whether to add or subtract in the formula.
PN-17	:	Yes, that's right, you should use the Pythagorean theorem, but why didn't you write the formula here?
GN-18	:	I forgot the formula, so I simply subtracted 50 from 120 (while pointing to the answer sheet).

Process Skill Error

At the process skill stage, subject FA did not make computational errors; however, the calculation was based on an inappropriate formula, as shown in Figure 4. The following excerpt from the interview illustrates this issue.

Table 8. Interview Responses of Subject FA at the Process Skill Stage

PN-21	:	So, what formula did you use to calculate the distance Andi traveled?
FA-22	:	I used the rectangle perimeter formula. I added the two known sides and then multiplied by two (while pointing to the answer sheet: $(50 + 120) \times 2 = 340$).

At the process skill stage, Subject GN made an arithmetic error during the calculation process, indicating a lack of procedural accuracy, as shown in Fugure 5. The following is an excerpt from the interview related to this matter.

Table 9. Interview with Subject GN Related to Process Skill Error

PN-19	:	Yes, that's right, you should use the Pythagorean theorem, but why didn't you write the formula here?
GN-20	:	I forgot the formula, so I simply subtracted 50 from 120 (while pointing to the answer sheet)

Encoding Error

At the encoding stage, Subject FA did not write a concluding statement or unit due to time constraints, as shown in Figure 4. The following is an excerpt from the interview related to this matter.

Table 10. Interview with Subject FA Related to Process Encoding Error

PN-23	:	Oh, I see. So the distance Andi traveled to return to the starting point is 340. What unit is that? You didn't include the unit here.
FA-24	:	The unit is meters. I didn't have time to write it because the time ran out.
PN-25	:	Oh, is that why you didn't write the final conclusion of your answer
FA-26	:	Yes

At the encoding stage, subject GN provided an incorrect final answer as a consequence of errors made in the earlier stages of problem solving, as shown in Figure 5. The following is an excerpt from the interview related to this matter.

Table 11. Interview with Subject GN Related to Process Encoding Error

PN-19	:	Yes, that's right, you should use the Pythagorean theorem, but why didn't you write the formula here?
GN-20	:	I forgot the formula, so I simply subtracted 50 from 120 (while pointing to the answer sheet).

Overall, the results indicate that transformation and encoding errors were the most prominent errors experienced by the students. These findings suggest that students' difficulties were not limited to computational skills but were closely related to conceptual understanding and the ability to translate real-world problems into appropriate mathematical models.

3.2. Discusion

The findings of this study reveal that eighth-grade students experienced various types of errors when solving Pythagorean theorem problems, as classified by Newman's Error Analysis (NEA), including reading, comprehension, transformation, process skill, and encoding errors. However, the distribution and characteristics of these errors varied between the two research subjects, indicating differences in students' conceptual understanding and problem-solving processes.

3.2.1 Error Analysis of Subject FA

Based on the results of the analysis, subject FA made errors at four stages of the Newman's Error Analysis (NEA) procedure, namely reading error, comprehension error, transformation error, and encoding error.

At the reading stage, subject FA demonstrated difficulty in accurately interpreting symbols and terminology, particularly the unit of measurement used in the problem. This finding indicates that reading errors may occur when students fail to attend carefully to mathematical symbols and textual information. Such errors are often associated with students' tendency to read problems superficially or hastily. This finding is consistent with the opinion of Anisa et al. (2023), who state that reading errors occur because students work hastily when solving problems, causing them to read the problem only once. Rahmawati & Permata (2018) also explain that students' reading errors include inaccuracies in interpreting sentences, difficulties in identifying key words in the problem, and incomplete reading of mathematical information and symbols presented in the problem.

At the comprehension stage, subject FA misinterpreted the phrase "shortest distance" as the perimeter of the rectangular field, which led to an incorrect understanding of the problem's objective. This finding suggests that comprehension errors occur when students are unable to relate linguistic expressions in word problems to appropriate mathematical meanings. Annisa & Kartini (2021) also argue that comprehension errors can cause students to fail to accurately represent what is happening, to understand and read the problem correctly, and to identify the required information, resulting in overlooked information and inconsistent information gathering.

At the transformation stage, subject FA made an error by incorrectly determining the formula or theory to be used to solve the problem. Subject FA applied the formula for the perimeter of a rectangle, whereas the problem should have been solved using the Pythagorean theorem. This error indicates that the student was unable to construct an appropriate mathematical model and failed to correctly transform the information given in the problem into a mathematical representation. This finding is consistent with the opinion of Rofi'ah, et al (2024), who state that common transformation errors made by students include incorrectly converting received information into a mathematical model, incorrectly determining equations, and failing to identify the correct steps to be followed in the problem-solving process.

At the encoding stage, subject FA made an error by not writing a concluding statement or including the appropriate unit of measurement. This was caused by time constraints and a lack of habit of writing a final answer or conclusion. This finding is consistent with the results of the study by Hoar, et al. (2021) which reported that encoding errors include failing to write a final conclusion, with an average error percentage of 45%.

3.2.2 Error Analysis of Subject GN

Based on the results of the analysis, subject GN made errors at three stages of the Newman's Error Analysis (NEA) procedure, namely transformation errors, process skill errors, and encoding errors.

At the transformation stage, subject GN was unable to formulate an appropriate mathematical model due to forgetting the relevant formula. These findings indicate that transformation errors occur when students fail to convert contextual information into suitable mathematical representations. The inability to identify the appropriate mathematical model suggests that students may recognize surface features of a problem without fully understanding its underlying structure. This result supports previous research Febryana et al. (2023) state that transformation errors can be observed when students do not know which formula should be used to solve a problem or choose an incorrect formula to solve the given problem appropriately. Rofi'ah et al. (2024) also state that common transformation errors made by students include incorrectly converting the received information into a mathematical model, incorrectly determining equations, and failing to identify the steps that must be followed in the correct problem-solving process.

At the process skill stage, subject GN made an error by failing to accurately carry out the procedure used. Subject GN made a mistake in the arithmetic operation, calculating $120 - 50 = 60$, whereas the correct result is 70. This error indicates that GN was less careful when performing calculations. Hoar et al. (2021)state that process skill errors involve computational mistakes, students' inability to correctly apply procedures or steps needed to solve problems, and carelessness during the calculation process.

At the encoding stage, subject GN's final answer was incorrect due to errors made in earlier stages. These findings suggest that encoding errors are closely related to students' habits in presenting solutions and summarizing results. Febryana et al. (2023) state that encoding errors can occur when students have correctly solved a mathematical problem but fail to provide the final answer in written form according to the problem requirements.

Pedagogical Implications

The findings of this study imply that mathematics instruction should place greater emphasis on conceptual understanding, mathematical literacy, and problem interpretation rather than solely focusing on procedural fluency and formula memorization. Teachers are encouraged to integrate contextual problems, visual representations, and guided questioning strategies to help students identify key information and select appropriate mathematical models. Additionally, explicit instruction on problem-solving stages, such as those outlined in Newman's Error Analysis, may assist students in developing more systematic and reflective approaches to solving word problems.

Limitations of the Study

This study is limited by the small number of research subjects, which restricts the generalizability of the findings. Furthermore, the analysis focused on a single Pythagorean theorem problem, which may not fully capture the range of students' problem-solving abilities. Future studies are recommended to involve larger samples and multiple problem types to provide a more comprehensive understanding of students' errors in solving geometric problems.

4. CONCLUSION

This study concludes that eighth-grade students at SMP Negeri 1 Banawa Tengah experienced various types of errors when solving Pythagorean theorem problems based on Newman's Error Analysis. The errors identified included reading, comprehension, transformation, process skill, and encoding errors, with transformation and encoding errors appearing most frequently. Differences between students were observed mainly in the frequency and stages of errors rather than in the types of errors themselves.

These findings indicate that students' difficulties are closely related to their conceptual understanding and ability to translate contextual problems into appropriate mathematical models. Therefore, mathematics instruction should emphasize conceptual learning and systematic problem-solving approaches to reduce students' errors.

This study is limited by the small number of research subjects; thus, future research involving a larger sample and varied problem contexts is recommended.

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