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ANALYSIS OF STUDENT ERRORS IN SOLVING TRIGONOMETRY PROBLEMS BASED ON THE NEWMAN PROCEDURE

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ABSTRACT

This study was motivated by student errors in trigonometry. This study aimed to describe the types of student errors in solving trigonometry problems using the Newman error analysis procedure. This research is descriptive qualitative with the subjects of vocational high school students. Data collection involved written tests, depth interviews, and documentation. The results show that most students made comprehension and transformation errors. The comprehension errors consisted of not writing down what was known and asked; immediately writing down the completion process with the wrong formula and incorrect understanding of the concept of the basic trigonometric formula. The transformation errors were not being able to transform information on the problem into the mathematical model, and incorrect in mentioning the formula.

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INTRODUCTION

Mathematics is important but most students still think mathematics is a difficult subject. This is in line with (Bakhri et al., 2019) saying mathematics is one of the subjects in schools that students rarely like. Mathematics is considered difficult by students because mathematical objects are abstract. Mathematics is abstract because objects or symbols in mathematics do not exist in real life. Abstraction (abstract thinking) in mathematics is critical because it is an ability that can describe situations/problems in mathematics (Nurhikmayati, 2017). Changing students' assumptions about mathematics being difficult can be done through the mathematics learning process. However, the mathematics learning process does not always run smoothly and successfully in practice. One of the reasons is the difference in the level of the students' initial abilities. Besides, it can also be caused by the lack of mastery of the subject. According to (Limardani et al., 2015), this can affect student difficulties in learning so that it allows errors in solving the problems on a certain subject.

Trigonometry is taught from high school to university, and it is closely related to limits, derivatives, and integrals. Some studies emphasized that trigonometry is a fundamental subject of algebra and geometry (Sarac, 2017; Zulfa et al., 2020). A strong understanding of trigonometry can improve students' cognitive skills (Sulistyaningsih et al., 2021) and critical thinking through reasoning and proof skills (Phonapichat et al., 2014).

Several studies found students' misconceptions about trigonometric concepts and trigonometric problems. Five types of student errors in trigonometry problems such as reading symbols did not understand the problem, mathematical modeling, and students inaccuracy in the answering process (Sulistyaningsih et al., 2021). The study of mathematics education student's errors using Newman in doing trigonometry problems is the misconception of the concept (Ahmad et al., 2018). The other student's error analysis found the students with medium logical-mathematical intelligence make some errors in finding connections and relationships of various mathematical structures (Sarkam et al., 2019). Setiawan (2021) proposed two errors in determining the value of the trigonometric functions which are error in using a method to determine the value of a special angle trigonometric function and error in understanding the information in the problem.

M. Anne Newman developed to analyze errors on written assignments known as Newman Error Analysis (NEA) or Newman Procedure. The Newman procedure has drawn two

particular attentions, such as the influence of language on mathematics learning and the inappropriateness of mathematics programs on the revision of standard algorithms (Clements & Ellerton, 1996). The hierarchy of the Newman procedure defines as the failure level of a problem, such as reading error (RE), comprehension error (CE), transformation errors (TE), process skill errors (PSE), and encoding errors (EE) (Newman, 1983).

According to Newman (Rahmawati & Permata, 2018), NEA was developed to help teachers deal with students who have difficulty with mathematical word problems. Students' errors found based on the Newman error analysis procedure are important in knowing the types of student errors in solving trigonometric problems. Based on information obtained from the types of mathematical errors made by students, teachers can use these references to determine appropriate learning strategies and minimize errors made by students on similar questions.

METHOD

This research is a qualitative research to understand the types of errors made by research subjects in solving math problems (Moleong, 2017). The aim is to describe in detail the student errprs in solving trigonometric problems based on the Newman error analysis procedure.

This research was conducted in one of vocational high schools in Brebes, Indonesia, involving 20 Year 10 students majoring in Fashion. The instruments used in this study were a test consisting of four trigonometry problems and an interview comprising five open-ended questions. Students' answers were obtained and analyzed to determine the errors. To find out the classification of student errors, the data obtained were analyzed using the Newman theory with the following indicators as seen in Table 1.

Table 1. Newman's Procedure and Indicator

No	Newman Procedure	Error indicator
1	Reading Error (RE)	The errors that students make when reading the questions
2	Comprehension Error (CE)	The errors made by students occur when students can read the questions correctly but do not know the problems referred to in the questions
3	Transformation Errors (TE)	The errors that occur when students can read the questions correctly can understand the information from the questions, but students fail to choose the right formula to solve the questions
4	Process Skill Errors (PSE)	The errors made in the steps to solve the problem
5	Encoding Errors (EE)	The errors are made when students can carry out the completion process, but the final result is wrong.

Determination of the category of student ability levels was carried out to take six subjects to be specifically analyzed and interviewed. Interviews were conducted to trace the student errors in solving trigonometry problems in more depth.

RESULT AND DISCUSSION

Based on the results of the analysis of the student answer sheets, it was found that the types of errors made by students based on the Newman error analysis procedure were RE, CE, TE, PSE, and EE. The form of student errors in solving trigonometry problems based on the Newman error analysis procedure in more detail can be seen in Table 2

Table 1. Students' Error Types

Number of Task	Student's Error Types				
	RE	CE	TE	PSE	EE
1	No student	No student	No student	S1, S2, S13	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S14, S16, S17, S18
2	No student	S3, S4, S5, S6, S7, S8, S18	S1, S2, S10, S13, S15, S16, S17, S20	No student	S12, S14
3	No student	S1, S2, S3, S4, S5, S6, S7, S8, S10, S13, S17 dan S19	S11, S20	S12, S14, S15, S18	S20
4	No student	S3, S4, S5, S6, S7, S8, S9, S14, S18	S1, S2, S11, S12, S15, S20	No student	S16

Table 2 shows that around 50% of students had errors according to the Newman procedure in solving trigonometry problems in each number. S10, S13, S14, S17, S18, and S20 made the most errors and had unique answers in solving trigonometry problems. Each student errors based on Newman error analysis will be discussed in more detail in the following sections.

Reading Error (RE)

Reading errors are mistakes that students make when reading the questions. Reading errors occur when students cannot read the words or symbols contained in the questions (Singh et al., 2010). In this study, all students were able to read the questions properly and correctly; students understood the symbols in the problems. So, there are no students who experienced the type of reading error. This is in line with research conducted by Halim and Rasidah (2019), stating that reading errors are rare or at small rate. One of the factors causing misunderstanding is that students do not read the problems carefully and miss the information (Sumule et al., 2018).

Comprehension Error (CE)

Comprehension errors are mistakes made by students that occur when students can read the questions correctly but do not know the problems referred to in the questions (Singh et al., 2010). In this study, comprehension errors are mostly made by low and medium-ability students. Comprehension errors occurred because the student missed the information and was incomplete write the information (Figure 1). The factors that cause misunderstanding, namely, students are not able to understand what is known students are not able to understand what is being asked

correctly (Jha, 2012). In this study, S10 did not write down what was known and what was asked; students immediately wrote down the completion process with the incorrect formula. The final result was also incorrect; students stated that students could not understand the information from the problems. S13, S14, and S17 also made the same error as S10. Figure 1 shows the results of the students' answers.

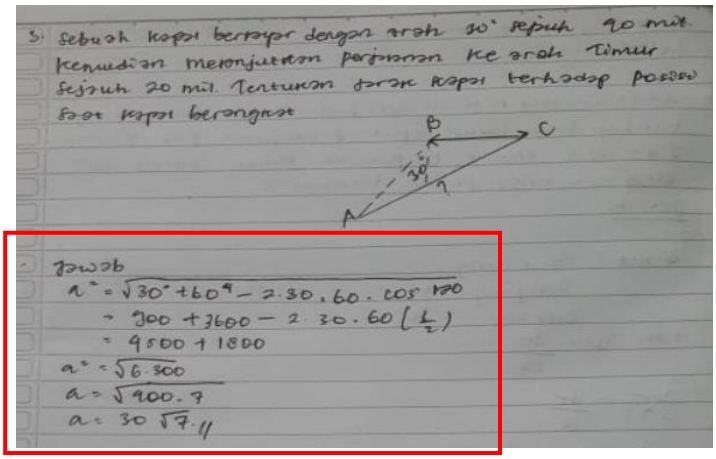

Figure 1. Comprehension Error

Figure 1 shows that students knew what was asked but did not write what they know. The students made mistakes in determining the formula and substituting the information from the questions. The student should have to calculate $\angle ABC$ to find the answer with the formula $AC^2 = AB^2 + BC^2 - 2.AB.BC.Cos\ ABC$. Based on the results of interviews with students for problem 3, students could not understand the questions well; students could not determine and explain the information from the questions appropriately. As a result, students cannot determine the right formula to solve problem 3. The students also explained that the problems given were difficult. The cause of students making mistakes was because students could not understand the problems well, carelessly worked on the problems, and lack mastery of trigonometry.

Figure 2 shows that students can determine what was asked but was incorrect in determining what was being asked so that the final result was incorrect. The problem is to find cos a^o, but the student wrote down to find sin a^o.

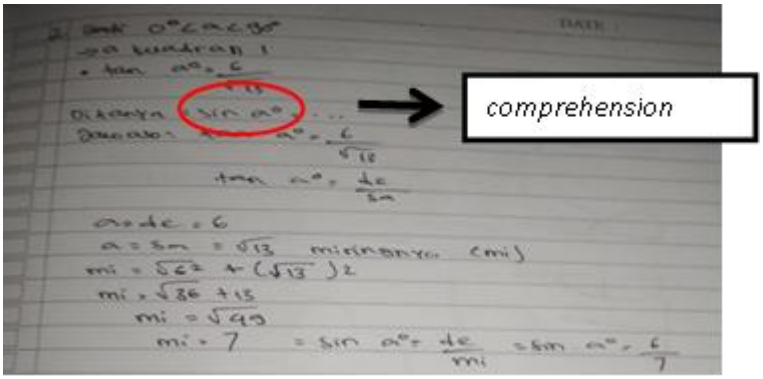

Figure 2. Comprehension errors

In this study, S10 made a transformation error in question number 2. S10 did not know the formula used to solve the problem. She/he incorrectly understood the basic trigonometry formula. S13, S17, and S20 also carried out transformation errors. Students said that they did not understand the concept of finding the value of sin, cos, and tan. Figure 3 is the answer of S20 to Problem 3.

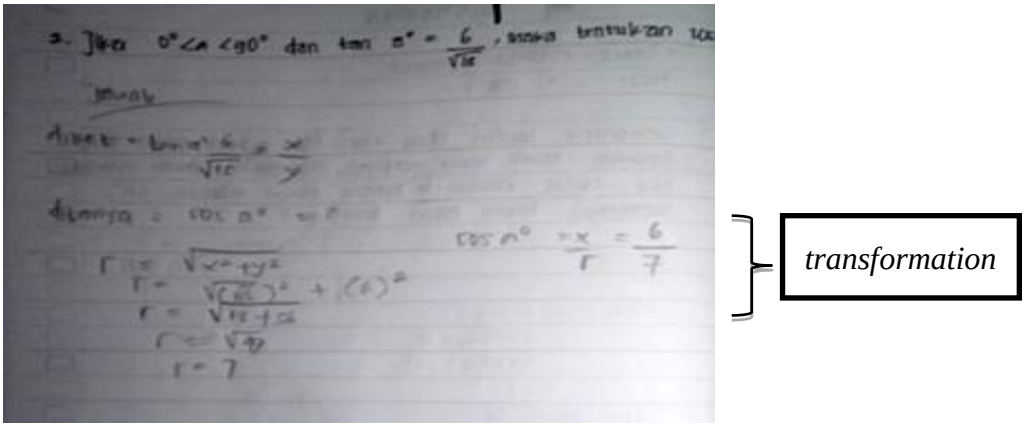

Figure 3. Types of transformation errors in problem 3

From Figure 3, it can be seen that S20 wrote what was known and what was asked exactly but she/he experienced a conceptual error for the formula of tan and cos. So, the final result was also wrong. Students admitted they were confused and did not understand how to determine the angle. The cause of students making mistakes is that students do not understand the concept of the formula from sin, cos, and tan.

Based on the results of interviews with students, students made some errors in mentioning what was asked. Therefore, they were wrong in determining the formula, resulting in incorrect final result. Students stated that they were not careful and rushed in working on the problems. The factors causing the type of comprehension error are also in line with the research

conducted by (Halim & Rasidah, 2019; Rahmawati & Permata, 2018; Wijaya & Masriyah, 2013), reporting that students made mistakes in understanding because they write down incomplete information from the problems.

Transformation Error (TE)

Transformation errors are errors in modeling mathematics or transforming the problem into a mathematical form (Dewi & Kartini, 2021). Transformation errors mostly occur in the students with low ability. In this study, students experienced the type of transformation error because they did not know the formula. They understood the formulas used but were wrong in writing the formula because they did not understand the concept of the trigonometry. The factors causing transformation errors was that students had no idea which formula to use (Jha, 2012). Figure 4 shows the students' answers.

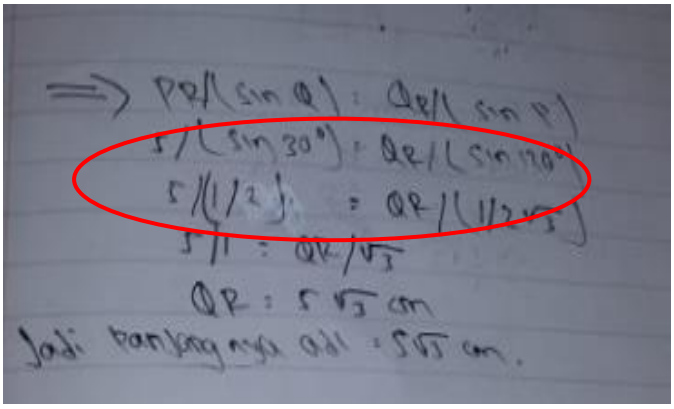

Figure 4. Types of transformation errors in Problem Number 4

Figure 4 indicated that students understood the questions and which formulas should be used to solve the questions, but they were not precise in writing the formulas, resulting in transformation errors. Based on the interview results, the students knew that the formula used was the sine rule formula. However, students used the incorrect formula that should be $\frac{QR}{\sin P} = \frac{PQ}{\sin R}$, resulting wrong result. The reason students made these errors because they did not understand the concept of the sine rules.

The cause of the type of transformation error is in line with research conducted by (e.g., Halim & Rasidah, 2019; Rahmawati & Permata, 2018; Rindyana & Chandra, 2012) reporting that students make transformation errors because the students did not know the method to be used.

Process Skills Error (PSE)

Process skill errors are mistakes made in the steps to solve the problem (Singh et al., 2010). Process skills errors are mostly made by students with moderate abilities. Several types of errors in process skills in this study were due to the students did incorrect multiplication and addition operations, substituting incorrect information from the problem into the formula used, being careless, and rushed in carrying out the calculation process. According to (Jha, 2012), the factor causing process skills errors is that students could not take steps to solve problems correctly and incorrectly in performing calculation operations.

S14 made a mistake in the skill process in question number 3. The student made a mistake in substituting the angle, wrong in performing the arithmetic operation, but the final result was the correct answer. This error happened because the students were confused in determining angles, not understanding the values of special angles, and being careless in performing the calculation. S18 also made the same error, namely error in determining the angle and the calculation process, so the final result was incorrect. Students stated that they were not careful in performing arithmetic operations and were confused in determining angles. Figure 5 shows the students' answers.

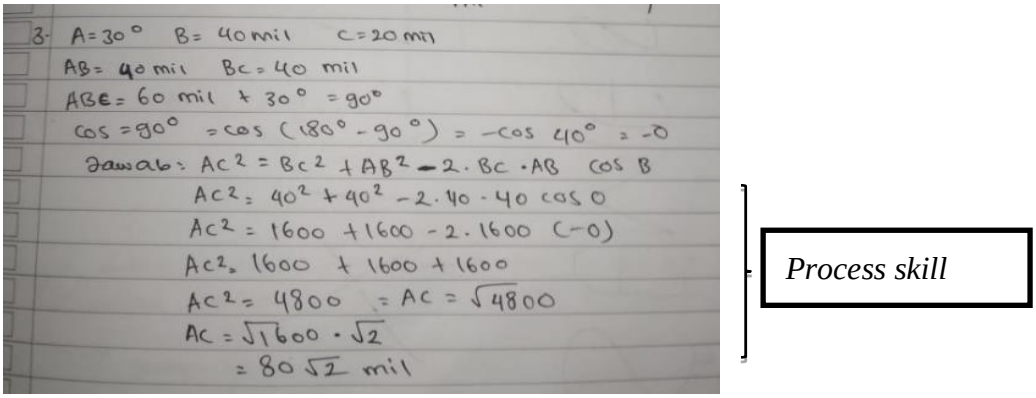

Figure 5. Types of process skills errors

Figure 6 shows that students write down what they knew and what was asked well. They also applied the completion method correctly, however they made mistakes in the completion process. Students were substituting incorrect information into the formula, resulting in incorrect results. Therefore, students experienced skill process errors. Based on the interview results, students mistakenly substituted the length of BC, incorrectly substituted the angle, and performing incorrect arithmetic operations. They worked on the problems while looking at

YouTube and Google and did not clearly understand the explanation from YouTube and Google. The students were not careful in doing calculating operations; students were confused in determining angles. The causes of process skills errors are in line with research conducted by (e.g., Rahmawati & Permata, 2018; Rindyana & Chandra, 2012; Utami, 2015), stating that process skills errors are due to incorrect calculation operations.

Encoding Error (EE)

Encoding errors are mistakes made when students can carry out the completion process, but the final result is wrong (Singh et al., 2010). The mistakes in writing the final answer were mostly made by low, medium, and high ability students. In this study, students experienced the type of error in writing the final answer because they did not write the unit at the end of the answer in the previous calculation process, and were careless in determining the final result. This is in line with Jha (2012) that the factor causing the error in writing the final answer is that students cannot find the final result accurately according to the completion steps and unable to write the final answer according to the conclusion in the problem. In this study, S10, S14, S18, and S17 made the same error, namely the error in writing the final answer to problem 1. Students did not write the units according to the questions because they forgot and careless in writing the final results. S13 made an encoding error in question number 1, where students already knew that the method used made mistakes in doing the calculation. Figure 6 shows the students' answers.

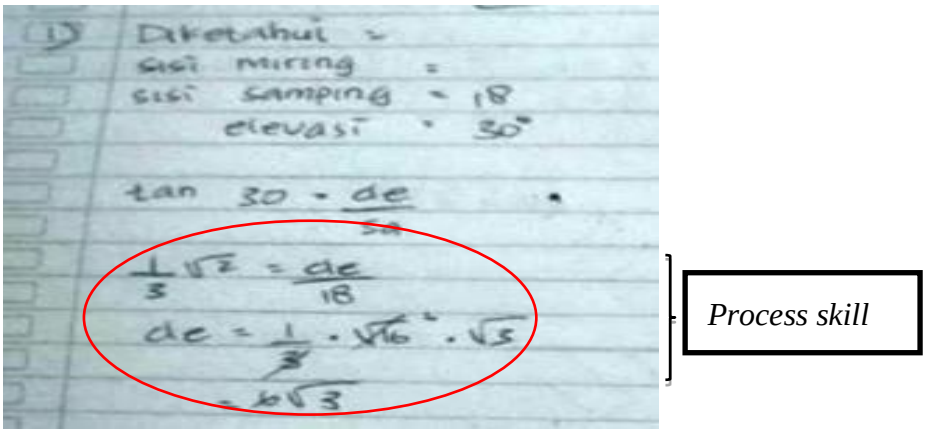

Figure 6. Type of Encoding Error

Figure 6 indicates that students wrote what they knew and what was asked correctly. They also wrote the formula correctly, but in the process of solving, students made mistakes in the calculation process. This error falls into the category of encoding skill. Based on interviews

with students, students could determine the formula correctly but made mistakes in writing down the steps. Students incorrectly mentioned the value of tan 30°, followed by the incorrect calculation. Encoding errors occur because students carry out the incorrect calculation process resulting in wrong conclusions and not writing units at the end of the answer (Darmawan et al., 2018; Wahidah et al., 2017).

CONCLUSION

Most students made comprehension and transformation errors. On the comprehension errors, students did not write down what was known and what was asked, they immediately wrote down the completion process with the incorrect formula and they did not understand the concept of the basic trigonometry formula. On the transformation error, students could not transform the information on the problem into the mathematical model; students mentioned incorrect formula. Meanwhile, most students made process skill errors due to errors in computation and carelessness in the calculation process, mainly due to students' weaknesses in manipulating mathematics. The solution to minimize student errors in solving trigonometry problems is explaining the concepts using concrete or real manipulative, students need to be trained to understand the problem in the whole problem. Students also need to be accustomed to solving word problems.

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