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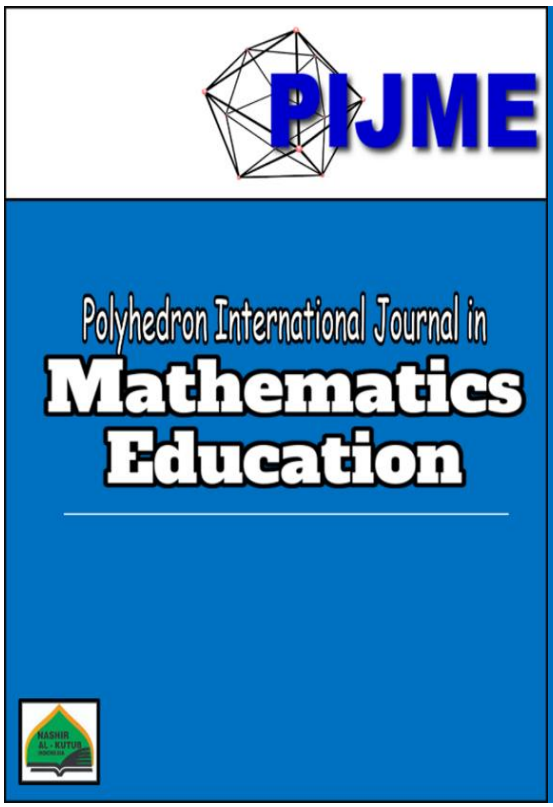

Analysis of students' errors in solving statistics problems based on Newman's Error theory: a study on high school students

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Original Article

Analysis of students' errors in solving statistics problems based on Newman's Error theory: a study on high school students

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Abstract
This study analyzed the errors made by high school students in solving statistics problems based on Newman's Error Theory. Statistics is a complex topic that requires accuracy and precision, leading to frequent errors in problem-solving. This research employed a qualitative approach using test questions and interviews to identify the causes of errors. The research subjects were eleventh-grade students who met the criteria of making errors in the predetermined indicators. Data analysis was conducted through three stages: data reduction, data presentation, and conclusion drawing. The findings revealed that reading errors were minimal and did not significantly affect problem-solving, while comprehension errors occurred due to students' lack of understanding of the problem statement. Transformation errors arose when students struggled to convert word problems into mathematical expressions, and process skill errors were observed when students performed incorrect calculations. Encoding errors occurred when students failed to write the final answer, provided incorrect final answers, or drew inaccurate conclusions. These findings indicated the need for targeted instructional strategies to address specific types of student errors. Teachers should have emphasized improving problem comprehension, enhancing mathematical translation skills, and strengthening students' ability to perform accurate calculations. By addressing these issues, educators could have supported students in developing a more structured and precise approach to solving statistical problems, ultimately improving their overall mathematical proficiency.

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1. Introduction

Statistics is a science used to collect, analyze, conclude, and interpret numerical data (Margueritte, 1892). Statistics play an essential role in data processing and presentation. It is divided into several sections, one of which is data distribution, which functions as an illustration of how far the values in a dataset deviate from the central value. In statistics, data distribution consists of range, quartile deviation, mean deviation, and standard deviation.

Each component of data distribution—range, quartile deviation, mean deviation, and standard deviation—presents unique challenges in problem-solving, making it difficult for students to solve related questions. This aligns with field observations showing that many students struggle with mathematical problems, particularly in statistics (Rosmiati et al., 2021). Murtiyasa and Wulandari

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(2020) identified several difficulties students face when solving problems: (1) inability to understand the problem, (2) lack of ability to determine appropriate steps for solving the problem, (3) difficulty interpreting the problem, and (4) inability to apply mathematical concepts correctly. Mansur and Subanji (2021) explained that students' errors in problem-solving result from difficulties experienced during mathematics learning. Common errors include a lack of conceptual understanding, inaccuracy in answering questions, misinterpretation of systematic solutions, and errors in calculations (Usqo et al., 2022). Therefore, it is necessary to analyze where students make mistakes in solving problems.

Student analysis can include observation, testing, examination, study, investigation, and interpretation of errors (Cahyani et al., 2022). Error analysis involves identifying mistakes in students' work when solving given problems. In this study, student errors are examined using Newman's Error Theory. According to Newman's classification (Rahayu & Pujiastuti, 2018), errors are divided into five types: reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors. Rohmah and Sutiarso stated that Newman's analysis can be used to identify students' written errors, determine the types of mistakes made, and uncover their causes. Several studies have shown that students make errors when solving mathematical problems, particularly in statistics, making it necessary to analyze and identify the causes of these errors.

Several studies have examined student error analysis in statistical problem-solving based on Newman's Error Theory. Research by Suryanti et al. (2020) focused on analyzing errors in High Order Thinking Skills (HOTS) questions. The findings revealed that reading errors resulted from a lack of careful reading, comprehension errors occurred when students failed to state given information and the question, transformation errors stemmed from the failure to apply formulas or understand solution methods, process skill errors were caused by misconceptions in constructing concepts, and encoding errors resulted from incorrect conclusions or failure to write conclusions. Another study by Jelyani Feronika et al. (2023) examined errors in solving statistical problems among 27 university students. This study analyzed students' answers and conducted interviews to determine the causes of errors. The results showed that each Newman error indicator had a 20% occurrence rate, with primary causes being lack of precision and incorrect calculations. Habibah et al. (2020), this study concludes that students' errors in solving word problems on the System of Two-Variable Linear Equations generally occur in the process skills stage and final answer writing, caused by unfamiliarity with the Newman procedure, difficulty in translating word meanings into mathematical models, and lack of practice. Sudirman (2016), this study concludes that students' ability to solve problems on the topic of triangles generally needs improvement through a better understanding of concepts to formulate appropriate solution procedures. Additionally, the most common errors based on Watson's criteria occur in the indicators of inaccurate data (id), incorrect procedures (ip), and skill hierarchy problems (shp).

Based on the above discussion, this study aims to identify students' errors in solving statistical problems. Therefore, the main question in this study is What are the common errors students make in solving statistical problems, and how can these insights inform more effective teaching strategies in statistics? Additionally, this research is beneficial for understanding how statistics can be effectively taught to students. The findings provide insight into the difficulties students face in problem-solving and can inspire educators to design better instructional strategies, ultimately improving students' learning outcomes.

2. Method

This study employed a qualitative approach, examining events that occurred in the learning environment to explore how subjects worked on statistical material and identify errors. Using this method, the researcher described students' work, identified mistakes, and analyzed their causes based on Newman's error classification. The research subjects were eleventh-grade students who met the criteria of making errors in the predetermined indicators. Data collection techniques used in this study included written tests and interviews. The written test consisted of three open-ended statistical questions designed to diagnose students' errors based on Newman's analysis, while interviews were conducted to explore the reasons behind students' mistakes in solving statistical problems. The research instrument used in the form of test questions was as Figure 1.

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Figure 1
Test Questions

1. Diberikan sekumpulan data sebagai berikut : 15,15,8,9,10,7,11,12,12, tentukan nilai variansi dari data diatas
2. Kecapatan mobil yang melewati jalan tol Malang-Surabaya di KM 84 selama 2 menit (dinyatakan dalam km per jam) dicatat dan disajikan dalam tabel berikut :

Kecepatan	70	80	90	100	110
Frekuensi	6	8	2	4	2

Tentukan Simpangan rata-rata dari kecepatan mobil yang melintasi jalan tol malang surabaya km 84 diatas.
3. Diketahui 30 siswa mengikuti suatu ujian. Jika skor maksimum tidak diperhitungkan, rata-rata nilai mereka adalah 79 . Jika skor minimum tidak diperhitungkan, rata-rata nilai mereka adalah 81. Tentukan rentang (range) nilai mereka

The collected data were analyzed and categorized according to Newman's error indicators. The following table presented the Newman error indicators used to classify the mistakes made by students after completing the test.

Table 1
Newman's Error Indicators (Halim & Rasidah, 2019)

No	Error Stage	Error Cause Indicators
1	Reading Error	a. Students do not recognize/read or identify symbols in the question. b. Students fail to understand the meaning of each word, term, or symbol in the question.
2	Comprehension Error	a. Students do not fully understand the given information in the question. b. Students do not fully comprehend what is being asked in the question.
3	Transformation Error	a. Students are unable to create a mathematical model from the given information. b. Students do not know the formula required to solve the question. c. Students do not know the arithmetic operations needed to solve the question.
4	Process Skills Error	Students do not know the correct procedure or steps to solve the problem.
5	Answer Writing Error	a. Students are unable to determine the final result of the problem based on the procedure or steps used. b. Students cannot present the final answer correctly. c. Students fail to write the final answer according to the conclusion.

In this study, several stages were carried out. The first stage involved observing the research site, identifying problems found during the observation, and developing research instruments. After obtaining permission, the researcher returned to the site to collect data using the prepared instruments. The next stage was data reduction, where the collected data were summarized, categorized based on predetermined indicators, and refined to focus on key issues. This was followed by data presentation, which allowed for better understanding and interpretation of the findings. Finally, conclusions were drawn to ensure the validity of the analysis, making the research findings strong and reliable.

3. Results and Discussion

3.1 Results

In this study, based on the given test, the researcher selected two students as research subjects—students who made errors in solving statistical problems. Interviews were then conducted to obtain direct information from the research subjects. The students' errors in solving statistical problems were then described. The explanation of these errors is as follows:

Description of Errors and Analysis of Subject 1

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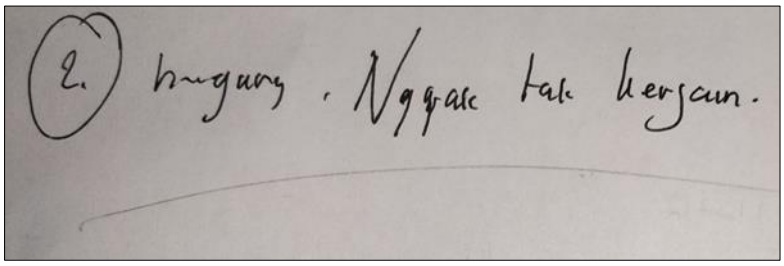
Figure 2
S1's Answer to Question No. 2



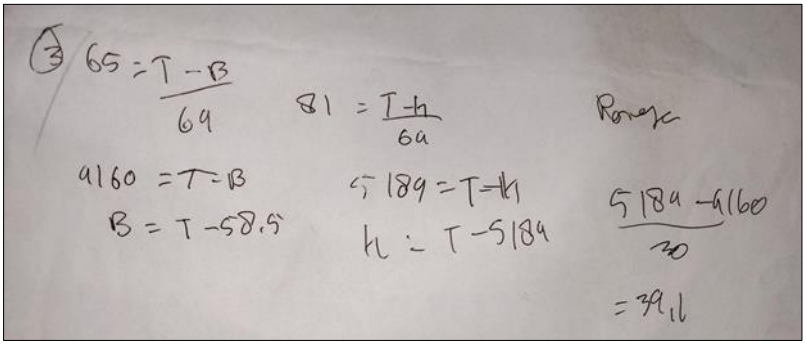
Based on Figure 2, it is evident that the student did not complete the given problem. The student was able to read the question but failed to understand it, transform it, and provide an answer from the initial stage to the final stage.

To identify the cause, an interview was conducted between the researcher and S1:

R: *"After reviewing your answers, why didn't you respond to the given question?"*
S1: *"I was confused about how to solve it."*
R: *"Before or during the test, did you refer to any materials, such as books, YouTube videos, or other learning resources?"*
S1: *"I watched YouTube, but I still didn't understand how to do it."*

Based on the test and interview data, S1's error stemmed from an inability to comprehend the problem, leading to a failure in answering it. This was due to a lack of understanding of the question's meaning and the correct solution approach. Thus, S1's error falls into the category of misunderstanding the problem.

Figure 3
S1's Answer to Question No. 3



Based on Figure 3, the student followed three stages according to Newman's Error Analysis: reading, problem transformation, and process skills. However, errors occurred in understanding the problem and writing the final answer. To investigate the causes, an interview was conducted:

R: *"Can you read question number 3?"*
S1: *"It's about determining the range of values for 30 students."*
R: *"Correct. I noticed an issue with your range calculation. Can you explain your method?"*
S1: *"I forgot."*
R: *"Try to recall how you solved it."*
S1: *"I searched for a tutorial on Google and followed the method I found there. The formula was (T - B) ÷ 64 - 1. Since T - B = 4160 (from 65 × 64), I used that. Then, the minimum score was 30, and I calculated 5184 ÷ 30, getting 34.1."*
R: *"Why did you subtract 5184 from 4160 and divide by 30?"*
S1: *"I don't know; that's how it was done on Google."*
R: *"Are you confident in your answer?"*
S1: *"Yes."*
R: *"To determine the range, you first need to find the maximum value by multiplying the average score by the number of students. What should the calculation be?"*

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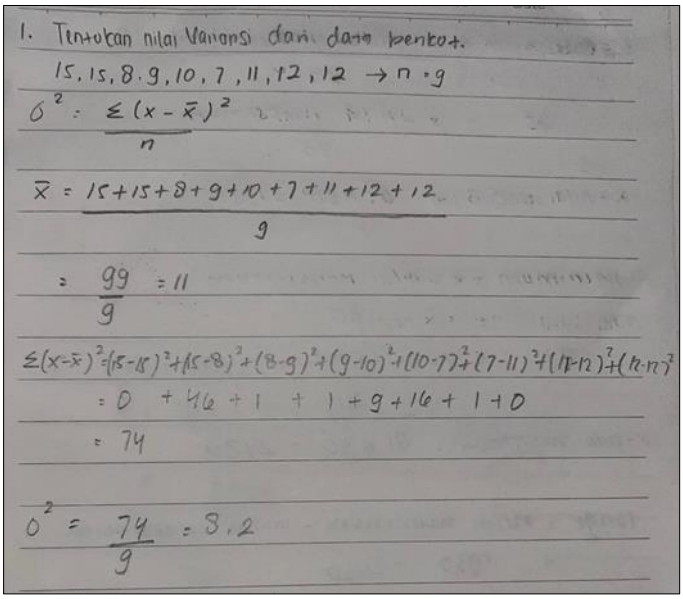
S1: *"65 × 30 = 1950."*
R: *"Correct. Now, what about the maximum value?"*
S1: *"81 × 30 = 2430."*
R: *"Now, to find the range, subtract the minimum value from the maximum."*
S1: *"2430 - 1950 = 480."*
R: *"So what's your final answer?"*
S1: *"15."*
R: *"And your initial answer was?"*
S1: *"34."*
R: *"So next time, be more careful in solving range problems."*

Based on the interview and test results, S1 made errors in writing the solution and using the incorrect formula. Instead of properly calculating the minimum and maximum values, S1 followed an incorrect online method, leading to transformation errors, process skill errors, and solution errors.

Description and Analysis of Subject 2

Figure 4
S2's Answer



Based on Figure 4, S2 successfully completed the problem but failed to write the correct final answer. S2 followed four stages: reading, understanding, problem transformation, and process skills. To identify the cause of the errors, the following interview was conducted:

R: *"Can you explain how you solved the problem?"*
S2: *"I used the data to calculate variance."*
R: *"I noticed some errors in your variance calculation. When solving variance problems, after finding the average, how do you calculate the deviation?"*
S2: *"I think I used the data values incorrectly."*
R: *"How should you have calculated it?"*
S2: *"By subtracting the data value from the variance?"*
R: *"Variance or something else?"*
S2: *"It should be the data value subtracted correctly."*
R: *"To find the deviation, you subtract the data value from the mean. Your calculation lacked accuracy in this step."*
S2: *"Okay."*

Based on the interview, S2 made errors in finding data deviations for variance calculation. Instead of using the mean, S2 subtracted consecutive data values and divided by the total number of data points, leading to process skill errors and final answer errors. These errors indicate confusion in problem-solving, resulting in incorrect final responses.

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3.2 Discussion

Based on the interview results and the statistics problem-solving test, both Subject 1 and Subject 2 made mistakes in their work. However, not all the questions provided contained errors made by the subjects. Below is an explanation of each based on the types of mistakes according to the test results performed by Subject 1 and Subject 2.

Mistake in Reading

A reading mistake refers to the student's inability to read the information and keywords in the problem. At this stage, both Subject 1 and Subject 2 did not make any mistakes. Both were able to read the problem well and understood the sentences in the given problem, so both were able to immediately start working on the problem without asking about unclear parts of the question.

Mistake in Understanding the Problem

A mistake in understanding the problem can be identified through the written "known" and "asked" information. In this stage, Subject 1 made a mistake by not answering the question posed by the researcher during the interview. Subject 1 admitted that they could understand the sentence in the problem but could not comprehend the next steps to solve the problem, which led to Subject 1 not attempting to solve it. This aligns with research by Suryanti, Candra, and Kristian (2020), which explains that a misunderstanding of the problem is caused by students not writing down the known and the asked parts of the problem.

Mistake in Transformation

Mistakes in transformation can be identified through the mathematical language used to solve the problem. Subject 1 made a transformation error in their work by not writing down an answer as shown in Figure 2, which resulted in the absence of mathematical statements in the solution. In Figure 3, Subject 1 was able to transform the sentence in the problem into a mathematical expression, although there were still some errors in the process. Subject 2, on the other hand, could transform the sentence in the problem into a mathematical expression, so Subject 2 did not make significant transformation mistakes. This is consistent with the research by Suryanti, Candra, and Kristian (2020), which states that transformation errors are caused by not applying formulas and not understanding the correct solution method.

Mistake in Process Skills

Both Subject 1 and Subject 2 made errors in process skills during their problem-solving. They did not use the appropriate formulas or correctly input numbers into the calculations, leading to mistakes in their answers. Neither Subject 1 nor Subject 2 seemed to understand which formulas to use. During the interview, both subjects admitted to feeling confused by the number of formulas and thus used the data carelessly, sometimes simply adding or multiplying the numbers given in the problem. This is in line with the research by Jelyani et al. (2023), which mentions that errors in process skills are caused by an inability to perform calculations correctly when solving problems.

Mistake in Writing the Answer

Both Subject 1 and Subject 2 made mistakes in writing the answers, as shown in Figures 2, 3, and 4. The errors in writing the answers were due to incorrect additions performed by both subjects during the problem-solving. Additionally, neither Subject 1 nor Subject 2 wrote the final conclusion regarding the problem and their answers. During the interview, the cause was identified as incorrect use of formulas and careless work, which led to errors in the final summation and lack of precision. Research by Feronika et al. shows that mistakes in writing answers are caused by a lack of student attention in drawing conclusions and failing to write down the final results.

4. Conclusion

The most common type of mistake made is the error in process skills during problem-solving. The cause starts from not using the correct formulas, entering the wrong numbers for operations, and not knowing the formulas needed to solve the problems, leading to mistakes in writing the final answer, which are caused by errors in the process of solving. As for other types of errors, such as reading mistakes, there were not many errors made, and there were no transformation errors because the students were able to convert the problem's sentence into mathematical expressions. However, in terms of understanding the problem, there were some errors where one of the answers was not written down due

to a lack of understanding of the problem. In this case, reading mistakes did not cause many errors, while the misunderstanding of the problem was due to students not knowing how to approach solving the problem, leading them to not write down the answer. To prevent recurring errors in solving statistics problems, students are expected to read and understand statistical material more thoroughly. Teachers should focus on strengthening students' process skills by emphasizing the correct use of formulas, guiding students on accurate data entry for operations, and reinforcing strategies for identifying the appropriate formulas needed to solve statistical problems. Additional instructional strategies should be developed to enhance students' problem comprehension skills, such as step-by-step problem analysis exercises, to prevent errors stemming from a lack of understanding and to ensure students can approach and complete statistical problems effectively.

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Conflict of Interest:
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