

ANALYZING STUDENTS' ERRORS ON THE TOPIC OF STATISTICS USING WATSON'S CRITERIA

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Abstract

This research is titled "Analysis of Student Errors in Statistics Material Based on Watson's Criteria," which aims to identify in depth the mistakes made by students in solving statistics problems. This study uses a qualitative approach with a descriptive method, so the results obtained emphasize more on descriptive explanations regarding the forms and types of errors that occur. The research subjects were 12th-grade students at Madrasah Aliyah AL AMIN, Kuningan Regency, who were chosen because they were considered to have received statistical material but still encountered various obstacles in the learning process. Research data were obtained through written tests and interviews designed to further explore the reasons why students made errors. Based on the analysis, it was found that student errors can be categorized into eight Watson criteria, including incorrect procedures, missing data, manipulation errors, and errors in interpreting problems. Although some students are able to arrive at the correct answers, the process of solving problems is often not systematic and skips important steps, indicating weaknesses in understanding basic statistics concepts. These findings suggest that improvements are still needed in teaching approaches so that students not only focus on the final results but also understand the problem-solving process thoroughly. By understanding the dominant types of errors, educators can develop more targeted learning strategies, provide constructive feedback, and create more comprehensive evaluation methods. This research is expected to contribute to curriculum development and enhance the quality of statistics education, enabling students to achieve better learning outcomes.

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INTRODUCTION

Education plays a crucial role in the effort to create reliable and high-quality human resources. Quality education can produce graduates who possess the competencies required. Education not only equips students with mastery and skills related to the subject matter but also instills values and ethics needed in the professional world. Learning should not only focus on the outcomes achieved by students but should place greater emphasis on the learning process. Learning should not only focus on the outcomes achieved by students but should place greater emphasis on the learning process. This approach fosters a deeper understanding of the material, encourages critical thinking, and prepares students to navigate ethical dilemmas in their future careers (Yuyung et al., 2024; Habsy et al., 2024). This learning process is expected to provide understanding, intelligence, diligence, quality, and to shape the character, morals, or behavior of students that can be applied in daily life.

Mathematics learning has been taught to students from elementary school to universities. This shows that mathematics is one of the subjects that is very important to learn and plays a crucial role in the field of education. Mathematics supports the development of science and technology as well. One branch of mathematics called statistics plays an important role in developing conclusions based on data. In the context of education, a deep understanding of statistical material is very important, especially for students at higher levels, to help them grasp the analytical skills needed in this information era. However, although statistics is a fundamental subject, many students struggle to understand and apply statistical analysis concepts. This problem often arises in the delivery of material, which can hamper the learning process and students' understanding of the subject matter.

Previous research indicates that the difficulties faced by students are caused not only by a lack of conceptual understanding but are also influenced by several factors, such as gender and personal characteristics. Therefore, it is important to conduct a thorough analysis of students' problems in statistics material by considering various factors that may affect their understanding. It is expected that this study can provide a clearer picture of the issues commonly faced by students in statistics and the factors contributing to these issues. Thus, the findings of this research can serve as a guide for researchers in implementing appropriate interventions to improve students' understanding and performance in statistics.

Analyzing student performance on statistics material can be done using Watson's criteria, which identifies various types of student performance that may occur when discussing a topic. According to research conducted by Bernard, junior high school students in West Bandung experienced conceptual problems of 37.1% and procedural problems of 35.9% when analyzing statistical data. These conceptual challenges include difficulties in identifying and using the correct formulas, as well as difficulties in presenting the formulas required to solve problems (Sari & Bernard, 2020). This indicates that understanding basic statistical concepts is very important for students to identify problems in formula research.

Furthermore, Andini's research shows that gender also affects students' difficulties in analyzing statistical data. The study findings indicate that while students in the male

group consistently make errors based on incomplete and slow data, students in the female group show different patterns of mistakes (Andini & Sutirna, 2023). This research highlights the importance of considering gender differences in problem analysis, which can provide deeper insights into how to address the challenges faced by students.

In addition, Hana's research identified the problems faced by students using an idealist approach when dealing with statistical problems. This study shows that students with this personality type consistently encounter difficulties in understanding problems and applying relevant concepts (Hana et al., 2023). This indicates that students' personality criteria can also influence how they interact with learning materials, such as statistics. If mistakes and incorrect answers frequently occur, this can lead to other errors, resulting in low student learning outcomes. Therefore, it is necessary to identify and understand the causes so that the most appropriate solutions can be found. To determine the types of student errors, Watson's error criteria were used. According to Watson, there are 8 error criteria, namely inappropriate data (ID), inappropriate procedure (IP), omitted data (OD), omitted conclusion (OC), response level conflict (RLC), undirected manipulation (UM), skills hierarchy problem (SHP), and above other (AA) (Khasanah et al., 2023; Nuryah et al., 2020; Usqo et al., 2022). Watson's criteria can be used to analyze students' errors in solving mathematics problems, thus helping educators understand the difficulties faced by students and design appropriate interventions (Rusdiati et al., 2022; Sanwidi, 2018).

A category that helps in implementing more effective educational interventions. In their recent study, Aswin and Juandi (2022) conducted a systematic review on the application of Watson's criteria in analyzing student problems at various educational levels. They acknowledged that these criteria have been thoroughly used and provide useful information about students' error patterns. Overall, the use of Watson's criteria in student analysis and statistical contexts highlights the importance of systematic and data-driven research to understand and improve student performance. This is useful not only for curriculum development and teaching methods but also for more accurate statistical analysis in research. Based on the background that has been outlined, the researcher is interested in conducting a preliminary study entitled 'Analysis of Student Errors in Statistics Material Based on Watson's Criteria.

METHOD

This study is a qualitative research that uses a descriptive methodology with a didactic design approach or Didactic Design Research (DDR). Descriptive research aims to understand situations, conditions, or other mentioned matters, and the results are presented in the form of words and language (Raco, 2010). This research was conducted in the 12th grade, odd semester of the 2024/2025 academic year at a private school in Kuningan Regency, specifically at Madrasah Aliyah (MA) AL AMIN, which is located within a Pesantren complex, Kuningan Regency, West Java. The technique for selecting subjects in this study used a purposive sampling technique, namely based on the results of essay test questions.

The purpose of this study is to describe students' mistakes in solving mathematics problems related to statistics. To achieve this goal, test instruments were used, including

written tests and non-test instruments in the form of interviews. The instruments used consisted of essay questions on statistics material, comprising 4 essay questions, and an interview guide. The research instruments used in this study have been validated because the researcher adapted them from previous expert researchers. The first step is to give students a written test on statistics material. The second step is for the researcher to interview all subjects with the aim of obtaining additional data on the causes of students' mistakes in solving essay questions on statistics material. Method triangulation is carried out to test the validity of the data obtained. To determine the extent of the errors made by students, the formula presented below is used.

$$P = n \times N \times 100\%$$

Explanation :

P = Percentage of each type of student error.

n = Number of errors for each type of error.

N = Total number of errors for all types of errors

RESULTS AND DISCUSSION

This research was conducted at Madrasah Aliyah (MA) AL AMIN with the aim of providing a description of students' mistakes in solving statistical problems based on Watson's criteria. The test questions given in this study consisted of 4 essay questions. These questions were adopted from previously existing questions. The written test was conducted after the statistics material was fully explained. After the students completed their work, the researcher proceeded by grading the tests that the students had completed. These grades were then analyzed as the final step and as a guide to analyze student problems based on the results of the written test according to Watson's criteria. The results of the tests completed by students containing related errors and the results of interviews with students who made related errors will be presented in the respective sections mentioned.

Research on "analysis of student errors in statistics material based on Watson's criteria" is very important due to several logical arguments grounded in educational theory and previous research findings. First, analyzing student problems can provide insights into the difficulty's students face in understanding and applying statistical concepts. By understanding the types of problems encountered, teachers can implement more precise interventions to improve student comprehension. Watson's criteria, which identify various categories of errors, allow for a more systematic and structured analysis of the occurrences (Hana et al., 2023; Usqo et al., 2022).

In addition, the results of this study can contribute to the development of a more effective curriculum and statistical teaching methods. Educators can select learning materials that are more focused on areas that are difficult for students to understand by understanding the common problems that arise. Research by Ramadhini and Kowiyah shows that difficulties in explaining concepts and difficulties in writing are often the main causes of students struggling to understand mathematical concepts (Ramadhini & Kowiyah, 2022). Therefore, by analyzing students' problems using Watson's criteria, teachers can develop more effective teaching strategies to address these issues.

Finally, this research is also important for improving student learning outcomes. By understanding the challenges faced, teachers can provide constructive feedback and help students overcome their own challenges. This aligns with research showing that a better understanding of students' problems can help teachers create more effective long-term plans to enhance learning outcomes (Hana et al., 2023; Usqo et al., 2022).

Based on students' performance in analyzing the given statistical material, student problems are categorized using Watson's classification. Students' answers are used to identify the causes of the problems and provide solutions that can be used to reduce the difficulty level of these problems. The following are eight types of errors based on the exam results obtained.

Incorrect Data Error (*Inappropriate Data/ID*),

The type of error is inappropriate data or inaccurate data, where student issues involve the use of less accurate data, which is one of the main reasons in determining the value of a variable. Based on the analysis of the written test results completed by the students, no errors of the inappropriate data type were found.

incorrect procedural error (*Inappropriate Procedur /IP*),

The type of error known as inappropriate procedure is an error where students operate on a problem at the correct level but use an incorrect procedure or method. Based on the analysis of question number 2, students made this type of error. The error made by students in solving question number 2 was miscalculating the difference of a value. This error indicates that students do not fully understand or follow the correct method to solve the problem. The error occurred because the steps used in solving the problem were incorrect or did not align with the concept, even though the result was nearly correct. Based on the interviews conducted, the reason students make errors in the process of calculating differences is that they have not fully understood the basic concepts of difference calculation. This is in line with findings that show that student mistakes are often related to inadequate conceptual understanding, even though they can follow procedural steps that appear correct (Alzubi, 2023; Makonye & Fakude, 2016).

2. Nilai	frekuensi	x_i	$f_i x_i$
52 - 58	7	55	385
59 - 65	8	62	496
66 - 72	7	69	483
73 - 79	5	75	375
80 - 86	6	81	486
87 - 93	4	90	360
94 - 100	4	97	388
	<u>41</u>		<u>3005</u>

$\bar{x}_p : 41$

$$\bar{x} = \frac{\sum f_i x_i}{\sum f_i}$$

$$= \frac{3005}{41}$$

$$= 72,29$$

Figure 1. This error occurs when students use incorrect or inappropriate procedures.

This error can be caused by the steps used in the work that do not align with the basic concepts of mathematics. For example, research shows that procedural errors often occur when students have a weak understanding of the concepts underlying the procedures, so they are unable to apply the steps correctly even if the result is nearly correct (Makonye & Fakude, 2016; Şişman & Aksu, 2015). In addition, this error can also be triggered by pre-existing misconceptions that influence the way students think and solve mathematical problems (Alzubi, 2023)(Mutambara & Bansilal, 2022).

It is important to note that these procedural errors not only affect the final outcome but also indicate a need for better educational intervention. By providing a deeper understanding of basic concepts, teachers can help students avoid similar mistakes in the future. Research shows that a concept-based approach can enhance students' ability to solve mathematical problems more effectively (Setiawan, 2022; Whitfield et al., 2020). Therefore, it is important for educators to recognize and address these procedural errors appropriately, so that students can develop a better understanding and reduce mistakes in the future.

Missing Data Error (Omitted Data/OD),

The type of error known as omitted data or missing data occurs when students do not include all the information, steps, or data required in the problem-solving process, even though the final result may be correct. Based on the error analysis conducted by students on question 4, there was an incomplete solution; steps were skipped, indicating that students did not present the process thoroughly. Students only wrote down the results of their work without paying attention to the problem statement. Although the final answer was correct, the incomplete steps showed that certain data or process elements were missing. This indicates that students only included the results of their work without considering the problem statement in its entirety. Based on the interview results, the cause of the incomplete solution was due to a lack of attention to detail in mentioning all the information contained in the question. This shows that students only included the results of their work without fully addressing the problem. This indicates that students only list the results of their work without paying full attention to the problem statement. Although the final answer given is correct, the incomplete steps in this work reflect missing elements of data or process (Aziza & Eratika, 2022; Noutsara et al., 2021).

$$\begin{aligned}
 4. \quad M_b &= T_b + \frac{(d_1)}{d_1 + d_2} \times p \\
 &= 54,5 + \frac{(3)}{3+2} \times 10 \\
 &= 54,5 + \left(\frac{3}{5}\right) \times 10 \\
 &= 54,5 + \frac{30}{5} \\
 &= 54,5 + 6 \\
 &= 60,5
 \end{aligned}$$

Figure 2. Errors in data types or omitted data made by students.

Research shows that errors in problem-solving are often related to an inadequate understanding of the information needed to solve the problem. Students who cannot identify important information in the problem tend to miss crucial steps in the solution process, resulting in mistakes even if the final outcome appears correct (Agustiani, 2021; Annizar & Kumala, 2023). In addition, error analysis conducted by students can help identify areas where they need to improve their understanding and skills in solving mathematical problems (Hoz et al., 2023; Indrawatiningsih & Lestari, 2022). Therefore, although students may arrive at the correct answer, the incompleteness in the problem-solving process indicates a need for further attention to mastering the necessary steps in solving mathematical problems.

Missing Conclusion Error (*Omitted Conclusion/OC*),

The error type Omitted Conclusion, or missing conclusion, means that students did not work according to what was asked in the question and failed to draw a conclusion. Based on the analysis results, in question 1, the student made an incomplete mistake in the concept of mode; it is not enough to simply state that "there is a mode" without mentioning the specific value or the frequency of its occurrence. This information comes from a defined methodology, so correcting this element is an important step in the answer process. Based on the interview results, the cause of the mistakes is that students were not thorough with the instructions given in the question; they worked based on what they remembered when they first read the question without reviewing their answers first.

Furthermore, research by Fatmala et al (2020) highlights that students' mistakes in solving math problems are often caused by a lack of understanding of the material being taught and an inability to identify the steps required to solve the problems (Fatmala et al., 2020). This is reinforced by research by Nugraha (2023), which states that students who do not understand basic concepts will have difficulty forming accurate conclusions (Nugraha et al., 2023). In addition, Andini (2023) found that errors in writing conclusions also occurred among male and female students, indicating that this problem is common among students (Andini & Sutirna, 2023).

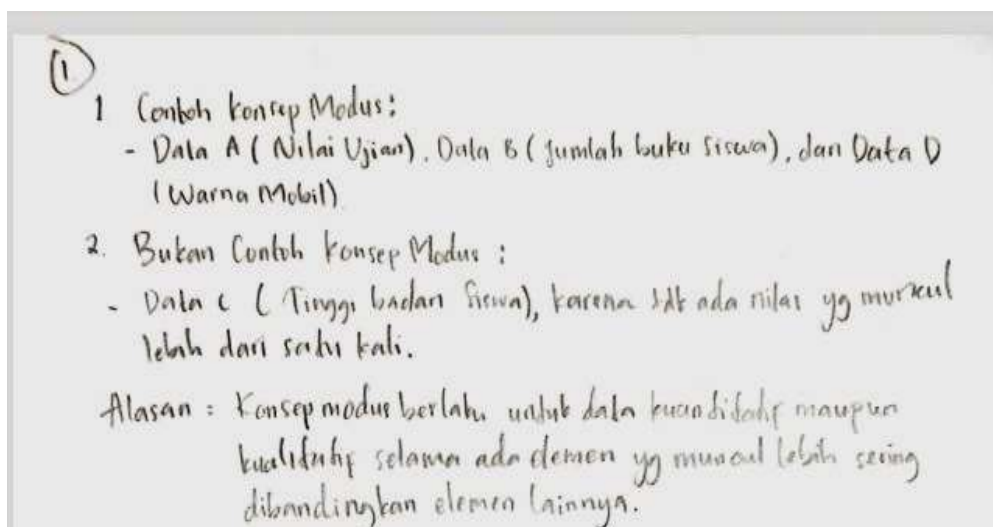


Figure 3. The type of error: omitted conclusion or missing conclusion made by students

Thus, it can be concluded that students' inability to explain the final step in solving mathematical problems is caused by various factors, such as a lack of understanding of the instructions, a lack of comprehension of the solving process, and difficulty in identifying the necessary steps. This emphasizes the need for more effective mathematics education to enhance students' understanding of the problem-solving process.

Response Level Conflict/RLC,

The type of response level conflict error is an error where a student demonstrates understanding at a certain level and then drops to a lower level in drawing conclusions. In other words, the response level conflict error is when a student writes an illogical answer. Based on the error analysis conducted by the student on question number 4, the student's error in work that is less systematic is due to the steps not being presented in order or logically; even though the result is correct, the confusion in writing or explaining the steps shows a lack of skill in organizing a neat and clear response. According to the interview results, the cause of the student's error in less systematic work is because the answer they wrote is understandable only to themselves and does not pay attention to the writing systematics.

Nilai Uts	f
25 - 34	6
35 - 44	8
45 - 54	11
55 - 64	14
65 - 74	8
75 - 84	6
85 - 94	6

$d_1 = 14 - 11 = 3$
 $d_2 = 14 - 12 = 2$
 $55 - 0.5 = 54.5$

$$\begin{aligned}
 M_o &= T_k + \left(\frac{d_1}{f_1 + f_2} \right) \times p \\
 &= 54.5 + \left(\frac{3}{7+2} \right) \times 10 \\
 &= 54.5 + \left(\frac{3}{9} \right) \times 10 \\
 &= 54.5 + \frac{20}{3} \\
 &= 54.5 + 6.6667 = 61.1667
 \end{aligned}$$

Figure 4. The type of conflict error at the response level or response level conflict made by the students.

Research shows that students often make mistakes in understanding and organizing systematic problem-solving steps. For example, students with different levels of mathematical ability may make errors in understanding problems, performing transformations, and drawing logical conclusions (Hadi et al., 2022; Saidah, 2022). This indicates that although students can arrive at the correct answers, their inability to organize the process logically reflects issues in conceptual understanding and the critical thinking skills required to solve mathematical problems (Bimantoro et al., 2024)(Ramadhini & Kowiyah, 2022).

Furthermore, this error analysis is important to help educators design more effective learning strategies. By understanding the types of mistakes made by students, educators

can provide appropriate interventions to improve students' skills in organizing steps of problem-solving in a systematic and logical manner (Sarah et al., 2023). Therefore, even though students may arrive at the correct answer, it is important to pay attention to the process they use in reaching that answer in order to develop better mathematical thinking skills.

Indirect Manipulation Errors (*Undirected Manipulation/UM*),

The type of error known as undirected manipulation or indirect manipulation occurs when students make mistakes in the process of manipulating numbers, symbols, or operations, such as adding, multiplying, or performing other mathematical operations incorrectly. Based on the analysis of student errors on question 3, there was a mistake where the student miscalculated, resulting in an incorrect answer. According to the interview results, the cause of the error was that the student worked according to their own understanding without paying attention to the numbers being calculated.

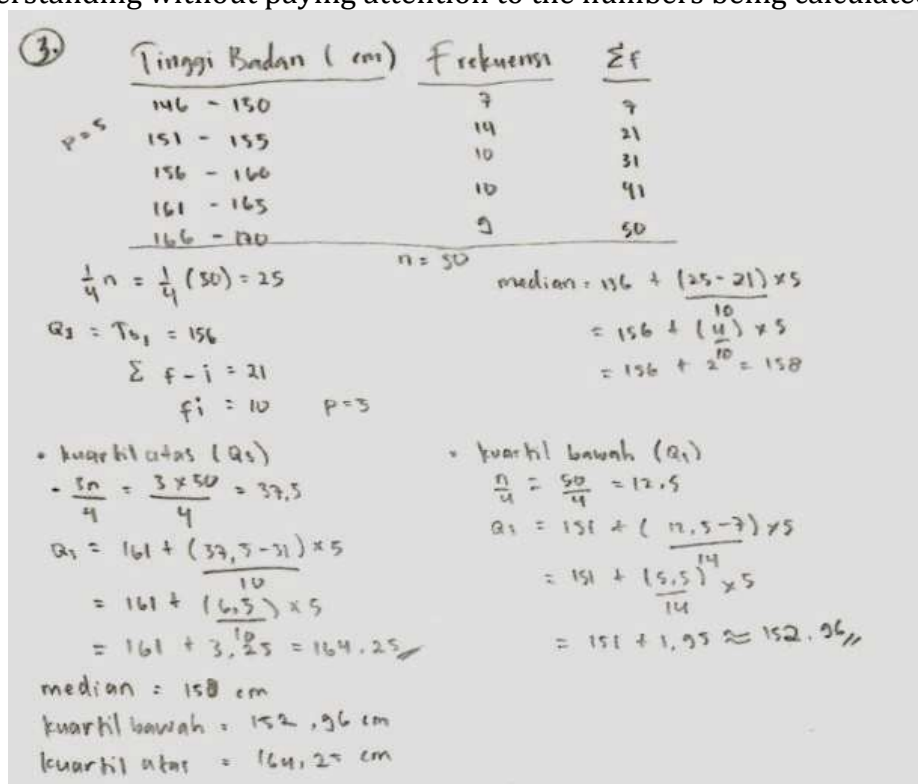


Figure 5. The type of indirect manipulation errors made by students

Research shows that errors in manipulating numbers are often caused by students' lack of understanding of the correct mathematical procedures. For example, students may make mistakes in adding or multiplying numbers, which results in inaccurate final outcomes (Dewi et al., 2023; Febrianti et al., 2024). In addition, other factors contributing to this error include carelessness in performing calculations and a lack of practice in solving similar problems (Afma et al., 2023; Elvi & Siregar, 2023).

Furthermore, this error analysis is important to help educators design more effective learning strategies. By understanding the types of mistakes made by students, educators can provide constructive feedback and design appropriate interventions to improve students' skills in performing number manipulations and other mathematical

operations (Siska Ayu Anggraeni, 2023). Therefore, even though students may arrive at the correct answer in some cases, it is important to pay attention to the process they use to reach that answer, in order to develop better mathematical thinking skills.

Skills Hierarchy Problem/SHP

The type of skills hierarchy problem is an error that occurs when students have difficulty applying the basic skills required to solve a problem. This issue indicates a lack of understanding of the fundamental concepts or procedures that should have been mastered beforehand. Based on the error analysis, students have a weak understanding of rounding numbers. Rounding numbers is a basic skill in mathematics that is often used in various topics, including statistics. Students do not fully understand the rounding rules (for example, rounding up if the next digit is ≥ 5 or rounding down if the digit is < 5), which indicates a problem with mastering basic skills. Based on interviews conducted, the cause of students making mistakes in rounding is that they have not fully understood rounding, leading them to incorrectly round the values that have been obtained.

Research shows that difficulties in understanding basic concepts, such as rounding numbers, can hinder students' ability to solve more complex math problems. Students who do not master basic skills often struggle to apply higher-level procedures, which impacts their learning outcomes (Nailia et al., 2023). In addition, factors such as low learning motivation and a lack of varied learning strategies can also contribute to students' difficulties in understanding these basic skills (Nailia et al., 2023).

Handwritten student work showing a frequency distribution table and a calculation for the mean. The table lists score intervals (Nilai), frequencies (Frekuensi), midpoints (X1), and weighted frequencies (Fixi). Below the table, the mean is calculated using the formula $\bar{x} = \frac{\sum f_i x_i}{\sum f_i}$.

Nilai	Frekuensi	X1	Fixi
52-58	6	55	330
59-65	7	62	434
66-72	6	69	414
73-79	4	76	304
80-86	5	83	415
87-93	3	90	270
94-100	3	97	291
	$\sum f_i$ 34		$\sum f_i x_i$ 2,458

$$\bar{x} = \frac{\sum f_i x_i}{\sum f_i}$$

$$= \frac{2,458}{34}$$

$$= 72,30$$

Figure 6. skills hierarchy problem performed by students

Therefore, it is important for educators to give special attention to mastering basic skills such as rounding numbers. By identifying and addressing the difficulties faced by students, educators can design more effective interventions to enhance students' understanding of fundamental concepts in mathematics (Ibrahim et al., 2022). This will help students build a strong foundation for learning more advanced and complex mathematics topics in the future. To achieve this, educators should implement targeted strategies, such as using manipulatives and engaging activities, to make learning more accessible and enjoyable for students with diverse learning needs.

Additionally, fostering collaboration among teachers, parents, and specialists can further support students in overcoming their mathematical challenges and improve overall learning outcomes (Topal & Ozsoy, 2024; Selvi et al., 2023). By creating a supportive learning environment that encourages open communication and shared resources. This collaborative approach can lead to more tailored educational experiences, ultimately benefiting students' mathematical proficiency and confidence (Topal & Ozsoy, 2024; Soon et al., 2025). By prioritizing collaboration and utilizing effective resources, educators can significantly enhance student engagement and achievement in mathematics (Angco & Angco, 2024). This collaborative framework emphasizes the importance of continuous professional development for educators, ensuring they are equipped with effective strategies to support diverse learners in mathematics.

CONCLUSION

The conclusion of this study indicates that analyzing students' errors in statistics material using Watson's criteria is crucial for understanding the difficulties they encounter. This study identifies various types of errors, such as incorrect procedural steps and missing data, which reflect students' weak conceptual understanding. By employing a qualitative descriptive approach, this study successfully collected data through written tests and interviews, allowing researchers to analyze the errors in depth. These findings provide valuable insights for educators to design more effective interventions in teaching statistics and to help improve students' understanding and performance. Furthermore, the results show that although some students may arrive at the correct answers, they frequently skip essential steps in the problem-solving process. This underscores the need for instructional approaches that emphasize a stronger understanding of fundamental mathematical concepts and the development of strategies that can assist students in overcoming these challenges. Thus, this study not only contributes to identifying students' errors but also offers guidance for developing more effective curricula and teaching methods in the field of statistics. Future research is recommended to explore students' statistical reasoning using broader participant samples and to integrate digital assessment tools that may provide deeper insights into error patterns and learning behaviors.

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