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Analysis of Students' Errors in Solving Probability Problems Based on Kastolan's Theory of Error Classification at Wesley Private Junior High School

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Abstract

Keyword: Conceptual errors, Procedural errors, Technical errors, Probability, Kastolan theory.

This study aims to analyze student errors in solving probability problems based on the classification of errors according to Kastolan's theory, which includes conceptual, procedural, and technical errors. This study used a qualitative, descriptive approach. The subjects were 25 ninth-grade students at Wesley Private Junior High School who had studied probability. Data collection techniques were conducted through written tests and interviews. Data were analyzed through data reduction, data presentation, and conclusion drawing. The results showed that students still make various errors in solving probability problems, including errors in understanding basic concepts, inaccuracies in formulating solution steps, and calculation errors. Conceptual errors occur due to a lack of understanding of the definition and formula of probability, procedural errors are caused by a lack of systematic solution steps, while technical errors are caused by a lack of accuracy in calculations. These findings indicate that students' understanding of probability still needs to be improved. Therefore, more effective learning strategies are needed to minimize student errors in solving probability problems.

1. INTRODUCTION

Mathematics education is a teaching and learning process aimed at developing students' understanding, skills, and abilities in mathematics. The primary goal of mathematics education is to equip students with the knowledge and skills necessary to solve problems, think critically, and make decisions based on data (Kurniati et al., 2025). Furthermore, mathematics education plays a crucial role in fostering logical, systematic, and analytical thinking skills, which are essential for addressing various challenges in both daily life and the advancement of science and technology. Through mathematics learning, students are expected not only to understand basic concepts but also to apply these concepts in various relevant situations (Safari & Nurhida, 2024). Therefore, mathematics education plays a strategic role in shaping students' intellectual abilities and preparing them to face future challenges.

Probability is a crucial component of mathematics education as it relates to the concepts of uncertainty and the likelihood of an event occurring. Probability is a number or measure used to express how likely something is to happen (Toruan, 2022). This concept is not only part of the mathematics curriculum in schools but also serves as a foundation for understanding various phenomena involving uncertainty. According to (Sofyeni et al., 2025), a good understanding of probability is highly beneficial for making decisions based on uncertainty, both in daily life and in more advanced scientific fields. Therefore, the concept of probability is taught to students so they can logically and systematically understand and analyze the various possibilities that arise in an event.

In line with the findings by (Salam & Sundayana, 2025), in the mathematics learning process, students often make various mistakes when solving problems related to the concept of probability. These errors generally occur because students have not fully grasped the basic concepts of probability, making it difficult for them to interpret the information presented in the

problems. Many students still hold misconceptions regarding the meaning of the probability of an event, resulting in solutions that often do not align with the correct conceptual framework (Maharani et al., 2022). This situation indicates that students' conceptual understanding of probability material still needs to be improved so that they can solve problems accurately and systematically. Therefore, efforts are needed to identify and analyze the errors made by students so that teachers can identify the sources of learning difficulties and design more effective learning strategies.

Error analysis based on Kastolan's theory is a technique that can be used to identify and analyze the errors students make when solving math problems (Ramadhini & Kowiyah, 2022). Kastolan (in Siregar et al., 2024) classifies errors into three categories: technical, procedural, and conceptual errors; these are the three categories of student errors identified in the classroom. Conceptual errors are those arising from an inaccurate or inadequate understanding of facts, principles, or concepts. Procedural errors are mistakes that occur due to inconsistencies in following the correct steps for solving a problem, such as an unsystematic sequence, failing to complete the solution to the final stage, or failing to simplify the answer. Meanwhile, technical errors are errors related to calculations and mistakes in writing mathematical symbols, coefficients, or constants (Sumargiyani & Ainurrahman, 2024).

Kastolan's theory is widely used in mathematics education research because it provides valuable diagnostic information for the learning process, as demonstrated in studies by (Rahmania & Rahmawati, 2016; Rena Fujirahayu et al., 2022). The results of this analysis can serve as a basis for designing more appropriate learning strategies, such as emphasizing conceptual understanding, refining problem-solving steps, or providing more targeted calculation practice. Therefore, the application of Kastolan's theory is considered relevant and effective for examining students' errors in solving

mathematical problems and for improving the quality of the learning process.

The objective of this study is to analyze students' errors in solving probability problems based on Kastolan's stages of error, which include conceptual, procedural, and technical errors, and to identify the factors causing these errors through the analysis of students' work and interviews, thereby providing a clearer picture of the difficulties students face in understanding probability material.

2. METHOD

This study employs a qualitative approach with a descriptive research design. The descriptive qualitative approach was chosen because it aims to deeply describe the forms of students' errors in solving probability problems without manipulating variables (Roosinda et al., 2021). This study refers to the error analysis framework according to Kastolan's theory, which classifies errors into three categories: conceptual, procedural, and technical errors.

The research subjects were 25 ninth-grade students at Wesley Private Junior High School who had studied probability. Data collection techniques in this study included written tests and interviews. The test was administered to students to identify errors in solving probability problems. The research instrument consisted of test questions designed based on probability learning indicators and structured to elicit potential errors consistent with Kastolan's classification.

Based on the test results, students will be categorized according to the type of error according to Kastolan. The interview respondents consisted of one student from each category, and the results of the interviews were used to explore in greater depth the causes of the errors made by the students.

Data analysis was conducted in three stages: data reduction, data presentation, and drawing conclusions (Haryono, 2020; Qomaruddin & Sa'diyah, 2024). Test data were analyzed by

identifying and categorizing students' errors into conceptual, procedural, and technical errors. Next, the patterns of errors that emerged were interpreted based on the solution steps written by the students. The analysis was supported by the assessment rubric in Table 1, adapted from (Hasibuan et al., 2022), to ensure that the classification of errors was carried out systematically.

Table 1 Error Assessment Rubric

Score	Error		
	Conceptual	Procedural	Technical
0	No theorem/concept	There are no steps	No calculations
2	Theorem/concept exists but incorrect	Steps are present but incorrect	Calculations exist but the results are incorrect
3	The theorem is correct but not quite accurate	The steps are correct but not entirely accurate	Calculations are correct but the results are not quite right
5	Theorem/concept that has been established correctly	The steps are correct	The calculations are correct and the results are correct

3. RESULTS AND DISCUSSION

The research procedure was carried out through the stages. The preparation phase involves developing test instruments based on content indicators and Kastolan's error classification. The implementation stage, which involves administering the test to students to obtain data in the form of student performance results. Data processing stage, which involves identifying students' errors based on the answers provided. Data analysis stage: grouping errors into conceptual, procedural, and technical categories.

Conclusion stage: formulating dominant error patterns and their implications for learning.

Based on Kastolan’s theory, this study was conducted by administering three open-ended questions as follows:

1. A coin and a dice are tossed simultaneously; what is the size of the sample space for that toss?
2. A bag contains balls numbered 1 through 10. If a ball is drawn at random, what is the probability of drawing a ball with a prime number?
3. Anton conducted an experiment by rolling two dice simultaneously 900 times. What is the expected frequency of the sum of the dice being 5?

The data collected in the form of student answer sheets contains students’ responses to the given questions. An analysis of these results was then conducted to identify students’ errors based on Kastolan’s error categories: conceptual, procedural, and technical errors.

Based on the analysis of the student answer sheets, the percentage of student errors is presented in Table 2, as follows:

Table 2 Percentage of Student Errors

Indicator	Q1	Q2	Q3
Conceptual Errors	24%	20%	40%
Procedural errors	20%	24%	44%
Technical errors	20%	28%	36%

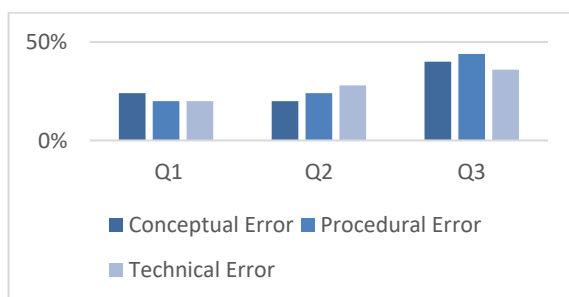


Figure 1 Student Error Percentage Diagram

Based on the analysis results for each question, it was found that in question

number 1, the percentage of conceptual errors was 24%, procedural errors were 20%, and technical errors were 20%. In question number 2, conceptual errors were 20%, procedural errors were 24%, and technical errors were 28%. Meanwhile, in question number 3, the percentage of conceptual errors was 40%, procedural errors were 44%, and technical errors were 36%. In general, procedural errors tended to dominate each question item, indicating that students still had difficulty in systematically compiling solution steps. Differences in percentages for each question also indicate that the level of difficulty and characteristics of the question influence the types of errors made by students. For a more in-depth discussion of each type of student error, the location of the error, and the causal factors are described as follows.

Conceptual Errors

3. Dik = 2 buah dadu
900 percobaan
dit : frekuensi harapan muncul mata dadu berjumlah 5
jawab : jumlah 5
(1,4) (2,3)
 $n(A) = 2$
 $n(S) = 6$
 $P(A) = \frac{2}{6} = \frac{1}{3}$
 $f_h = \frac{1}{3} \times \frac{900}{100} = 300$

Figure 2 Student Errors in the Conceptual Category

Based on the student's answers in Figure 1, it appears that the student made a mistake in understanding the concept of probability in throwing two dice. The student wrote that the pairs that produce a total of 5 are only (1,4) and (2,3), so that $n(A) = 2$. However, conceptually, the pairs that produce a total of 5 are (1,4), (2,3), (3,2), and (4,1), so that $n(A)$ should be = 4. This shows that the student does not understand that

the order of the dice pairs affects the results and must be taken into account.

In addition, the student also wrote that $n(S) = 6$, indicating that the student assumed the sample space consisted of only 6 possibilities. However, when throwing two dice, the correct sample space consists of 36 possibilities. This error indicates that the student does not fully understand the concept of sample space.

Based on these findings, it can be concluded that students experienced errors in understanding the basic concepts of probability, both in determining the sample space and in identifying the event in question. This aligns with Kastolan's theory, which states that conceptual errors occur when students fail to understand the definitions, principles, or relationships between concepts.

This conceptual error also indicates that students tend to memorize procedures without understanding the underlying concepts. As a result, when faced with problems requiring deeper understanding, students have difficulty determining the correct steps. Therefore, learning that emphasizes conceptual understanding is needed, for example by providing a variety of problems and encouraging students to explain their thinking processes.

Procedural Errors

1). Dik: .uang logam
. dadu
Dit: ruang sampel?
Jawab: $n(S)$ koin = 2
 = {A, G}
 $n(S)$ dadu = 6
 = {1, 2, 3, 4, 5, 6}
total : 2×6
 = 12

Figure 3 Student Errors in the Procedural Category

Based on the students' answers in Figure 2, it can be seen that the students have been able to determine the number of sample spaces for each experiment, namely 2 possibilities for coins and 6 possibilities for

dice, so that the total sample space is 12. This shows that the students have understood the basic concept in determining sample spaces.

However, in the solution process, students did not organize the steps completely and systematically. They did not write down the joint sample space in detail and did not state the events in question clearly, for example, in the form of event notation such as A_1 , A_2 , and so on. As a result, although the final result was correct, the solution process demonstrated did not depict a coherent flow of thought.

Based on this, the errors made by students fall into the category of procedural errors, which are errors that occur because the solution steps are not structured systematically. This finding aligns with Kastolan's theory, which states that procedural errors occur when students fail to follow the solution steps correctly, even though they have understood the basic concept.

This error shows that students are not yet accustomed to writing down the complete solution process, so there needs to be emphasis in learning so that students do not only focus on the final result, but also on systematic and structured solution steps.

Technical Errors

8). Dik: kantong berisi bola 1-10
Dit: peluang terambil nomor bil. prima?
Jawab: $n(S) = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$
 Prima = {2, 3, 5, 7}
 maka : $\frac{4}{10} = \frac{2}{5}$

Figure 4 Student Errors in the Technical Category

Based on the students' answers in Figure 3, it appears that they have a good understanding of the basic concept of probability. They are able to define the sample space, namely $S = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$, and can correctly identify prime numbers, namely 2, 3, 5, and 7. Thus, the number of desired events is 4 out of a total of 10 possibilities.

However, an error occurred at the final stage of the calculation, when simplifying the fraction. The student wrote down $\frac{4}{10} = \frac{3}{5}$, which should have been simplified to $\frac{2}{5}$. This error indicates an error in the simple arithmetic operation.

Based on this, the errors made by students are classified as technical errors, meaning errors that occur not due to a lack of understanding of concepts or procedures, but rather due to a lack of accuracy in calculations. This aligns with Kastolan's theory, which states that technical errors relate to errors in arithmetic operations or the final calculation process.

These technical errors indicate that students need to improve their accuracy in completing calculations, especially in the final stages. Therefore, teachers need to encourage students to double-check their calculations to minimize technical errors.

Based on these results, interviews were conducted with three students representing each error category: conceptual, procedural, and technical. Interviews with students who committed conceptual errors revealed that they remained confused about determining the sample space when rolling two dice. Students admitted to only listing the options they considered correct without considering all possible pairings and not realizing that the order of the pairs was also taken into account.

Interviews with students who made procedural errors indicated that they understood the question and were able to find the final solution, but failed to thoroughly record the steps. Students also revealed that they jumped straight to the final solution because they felt pressured and believed that recording the steps wasn't important.

Meanwhile, interviews with students who experienced technical errors revealed that they had a good understanding of the concepts and steps for solving the problems. However, they reported being less careful in their calculations, especially when simplifying

fractions, and failing to double-check their answers after completing the work.

Analysis of student answer sheets and interviews revealed that inaccuracies in solving probability problems included conceptual, procedural, and technical errors. Each error category manifested in different aspects of the problem, indicating that students' understanding of probability material remains suboptimal. This research is consistent with the findings of Afma et al, (2023), which classifies student errors into three main categories: conceptual, procedural, and technical errors.

A conceptual error is evident in the student's failure to fully define the sample space in the context of the experiment of rolling two dice. The student only listed a subset of the potential eligible pairs and ignored the importance of the order of the pairs. Furthermore, there is a misconception that the sample space consists of only a finite number of possibilities, when in fact, an accurate representation of the sample space includes 36 different outcomes. This scenario indicates that the student has not yet achieved a comprehensive understanding of the basic concepts of probability, particularly regarding sample spaces and ordered pairs. Students tend to list possibilities they believe to be accurate without thoroughly considering all available options. Consequently, the identified error aligns with the conceptual category, as it relates to a lack of understanding of the basic concept. This aligns with the statement Laksono & Pramesti (2022), who argues that conceptual errors arise when students cannot understand or apply concepts correctly.

Procedural errors were demonstrated through the haphazard formulation of the resolution steps. Although students successfully identified the final outcome, the recorded process was incomplete and failed to account for the correlation between the sample space and the event of interest. Students often skipped intermediate steps that led directly to the final answer without fully articulating the solution stages. This suggests that the

procedural aspects necessary to arrive at the correct answer have not been recognized as essential components of the problem-solving process. The observed irregularities in recording the procedure resulted in an opaque resolution process. This finding corroborates research Susilawati et al (2024) which states that procedural errors occur when students do not follow the correct solution steps, do not complete the problem to the final stage, and are unable to simplify the result correctly. Furthermore, the study also found that students often discontinue the solution process due to difficulties with the calculation steps.

Technical errors were evidenced by inaccuracies during the calculation phase, particularly at the intersection of fractional simplifications. At this stage, while students had an understanding of the concepts and steps required for the solution, errors arose from a lack of thoroughness. Furthermore, the lack of practice in verifying their work resulted in simple errors that went undetected. This condition underscores the need to increase the dimensions of thoroughness and caution in the calculation process. This observation aligns with the perspectives offered by Lutfia & Zanthi and Damayanti & Firmansyah in (Sepriliani et al., 2025), which states that technical errors stem from insufficient rigor in calculations and a failure to double-check results. Furthermore, Laksono and Pramesti (2022) also emphasized that technical errors are related to inaccuracies in arithmetic operations.

Based on the analysis of student work data and supported by interviews, it was discovered that the errors made by students were not limited to one type, but included conceptual, procedural, and technical errors. Interviews indicated that some students understood the formulas used but had difficulty explaining the steps in a coherent manner. This indicates a mismatch between students' understanding and their ability to apply it to problem-solving.

Of the three types of errors, procedural errors were the most common.

This predominance of errors indicates that students have prior knowledge of the concept of probability but are unable to systematically implement it in problem-solving. This finding aligns with research findings that indicate procedural errors are the most common errors among students. (Putri et al., 2025) This condition indicates that students tend to know the formula, but do not yet understand the sequence and reasons for using the solution steps correctly.

Furthermore, based on interview results, students tended to jump straight to the final answer without writing out the complete solution steps. This indicates that students are not yet accustomed to thinking systematically. Furthermore, students also admitted to having difficulty determining the sample space and the events in question, indicating errors in conceptual understanding. This finding aligns with research suggesting that student errors are caused by a lack of understanding of the core problem and an inability to accurately determine the sample space. (Hilmi et al., 2025).

Upon closer examination, the prevalence of these procedural errors is inextricably linked to students' misconceptions. Misconceptions are inaccurate understandings of a concept that students consistently use to solve problems. Students often go unnoticed, continuing to use these erroneous understandings in various problem-solving situations, potentially hindering the development of a correct conceptual understanding. (Arianta et al., 2023; Putri et al., 2024).

In conceptual errors, misconceptions are evident in students' inability to grasp the basic concepts of probability, particularly in defining sample spaces and events. Students often fail to distinguish between all possible outcomes and the event in question, resulting in errors appearing early in the problem-solving process. Mistakes at this stage are crucial because they will impact subsequent steps.

Furthermore, in procedural errors, misconceptions are evident in students'

inability to systematically organize the steps for solving a problem. Although students know the formulas used, they don't understand when and how they are applied. This often leads to students skipping important steps, not writing out the process completely, or jumping straight to the final result without going through the correct steps.

Regarding technical errors, misconceptions relate to an inaccurate understanding of the mathematical operations used in calculating probability. These errors generally occur in the form of errors in arithmetic operations, such as division or simplifying fractions. Although seemingly simple errors, they indicate that students do not yet have adequate mastery of the basic mathematical skills underlying the calculation process. Furthermore, technical errors are often influenced by students' lack of accuracy in carrying out calculation procedures, thus reinforcing the fact that basic skills remain a major weakness in problem-solving. (Bees et al., 2023).

When linked to learning theory, this condition can be explained through a constructivist approach, which states that knowledge is actively constructed by students based on their learning experiences. When students construct inaccurate concepts from the outset, these misconceptions tend to persist and carry over into subsequent problem-solving processes. Furthermore, learning that emphasizes memorizing procedures without a deep understanding of concepts also reinforces the occurrence of procedural errors. Students tend to simply memorize formulas without understanding their meaning, thus experiencing difficulties when faced with problems in different or non-routine contexts. This aligns with research findings showing that student errors in mathematics are largely influenced by weak conceptual understanding and the dominance of procedural-oriented learning rather than conceptual understanding. (Bees et al., 2023; Lebriansari, 2025).

Overall, these three types of errors are interrelated and form a continuous pattern of errors, where conceptual errors lead to procedural errors, which in turn lead to technical errors. This suggests that the errors are not only caused by a lack of thoroughness, but also by weaknesses in conceptual understanding and a lack of systematic thinking habits.

Thus, the predominance of procedural errors in this study not only reflects weaknesses in the problem-solving process but also indicates fundamental misconceptions among students. Therefore, mathematics learning needs to be designed to focus not only on the final result but also on the process and a deeper understanding of concepts, so that students can build sound knowledge and solve problems systematically and accurately.

This is in line with the findings (Farhana et al., 2025) in his research which states that conceptual errors occur when students misunderstand or misapply concepts related to a problem, procedural errors arise when students fail to find a solution, and technical errors are caused by a lack of accuracy in performing calculations. These findings indicate that student errors stem not only from a lack of understanding of the material, but also from inaccuracy in following solution procedures and a lack of accuracy in verifying the results of their work.

4. CONCLUSION

Based on the research results, students still experience errors in solving probability problems, including conceptual, procedural, and technical errors. Conceptual errors are evident from a lack of understanding in determining sample spaces and events, procedural errors from lack of systematicity in solving steps, and technical errors from a lack of accuracy in calculations. The results show that the most dominant error is procedural errors, caused by students' habit of not writing down steps completely and going directly to the final answer. In addition, errors are also influenced by a lack

of conceptual understanding and students' habit of not double-checking their work.

Based on these findings, improvements are needed in the learning process to minimize student errors in probability. Teachers are advised to use visual representations such as tree diagrams or probability tables to help students understand the sample space more concretely. By using tree diagrams, students can directly see the possible outcomes, thereby reducing errors in determining outcomes.

Furthermore, teachers need to provide practice problems in stages, starting with contextual and concrete problems and moving on to more abstract ones. This aims to ensure that students not only memorize formulas but also develop a deeper understanding of the concept of probability. Teachers are also advised to get students into the habit of writing down the complete steps for solving problems, from determining the sample space, the event in question, to the probability calculation process. This way, students can reduce procedural errors and develop more systematic thinking skills.

Furthermore, the use of group discussion methods can help students better understand concepts. Through discussions, students can exchange ideas and correct any misconceptions. By implementing this strategy, it is hoped that students will not only be able to solve probability problems procedurally but also understand the concepts comprehensively, thereby minimizing conceptual, procedural, and technical errors.

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