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STUDENTS' ERROR ANALYSIS IN SOLVING PROBABILITY STORY QUESTIONS BASED ON REVISED NEWMAN THEOREM

Dyah Nirmala Sani [1*], R. Rosnawati [2]

[1,2] Mathematics Education, FMIPA, Universitas Negeri Yogyakarta
Jl. Colombo, No. 1, Sleman, 55281, DI Yogyakarta, Indonesia

e-mail: [1] dyahnirmala.2018@student.uny.ac.id

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*corresponding author**

Abstract

Generally, students still need help working on story-shaped questions. This error is natural, but if it continues, it will harm the mastery of the next material. The ability to solve story questions is closely related to numeracy skills, therefore knowing the location of the difficulties using the revised Newman theorem and the causal factors will help students achieve higher learning outcomes. This research was a quantitative descriptive approach, with the research subjects of junior high school students as many as 152 students. The instruments used were diagnostic tests and questionnaires. Each had an estimated reliability of 0.701 and 0.705 with good qualifications. The results show that students' most frequent types of errors in solving story questions on empirical and theoretical probabilities were 43% transformation errors, 36% comprehension errors, 15% process skill errors and encoding errors by 6%. The specific factors of student errors are not thorough students, being in a hurry, having difficulty understanding the questions, did not master the material, forgetting the formula, hesitating in determining the formula, not re-check the answers, and were unable to write the final project answers/conclusions. Interest and motivation factors as well as society factors are the general factors that most influence the mistakes made by students.

Keywords: error analysis, story questions, Newman theorem, probability

1. Introduction

Mathematics is a difficult subject for most students (Kikas et al., 2020; Stoica, 2015). Even mathematics has transformed into a fear passed down from generation to generation, becoming the subject most feared by students (Mubair, 2011). Therefore, in general, in learning mathematics, concepts are given first, followed by questions in the form of stories, known as story questions. Problems in the form of stories in mathematics are problems that exist in everyday life, which are then solved by procedures and operations that exist in mathematics (Raharjo & Waluyati, 2011). The understanding of mathematical story questions is a set of problems that can be solved by procedures, operations, and formulas that exist in mathematics (Gasco & Villarroel, 2014). The story questions that have been compiled by story questions that is related to the reality that exists in real life. The story questions contain questions that cannot be answered directly by students but with non-routine procedures and exams that have been known in advance by students (Ashlock et al., 1980).

Through story problem-solving, students are trained to use mathematics in everyday life. This ability is very closely related to numeracy abilities. Numerical ability is the ability of students to count on solving problems in mathematics and real life (Ackland, 2014). Numerical ability is thinking using concepts, procedures, facts and mathematical tools to solve everyday problems in various contexts (Kemendikbud, 2020). In contrast to numeracy, where the scope of context is generally detailed, the story does not specifically indicate the breadth of the context to be measured. However, it can train students to develop supporting students' numeracy skills. The numeracy problems are story problems, but not the other way around.

One of the topics in junior high school is probability. This study on basic competencies produces a broad range of teaching materials used to develop indicators of competency achievement. Following the basic competencies, the material is an empirical probability, understanding sample space, sample points, events, multiple events, theoretical probabilities, a frequency of expectations and a complement of probabilities. The ability of Indonesian students in the material of probability still needs to improve. It can be seen in the results of the 2019 National Examination (Kemendikbud, 2019) that the absorption capacity of calculating the probability of dice drawing data and solving probability problems in daily questions is 46.53% and 61.03%, respectively. The students' comprehension between 90% - 100% is very good, 80% - 89% is good, 70% - 79% is acceptable, and less than equal to 69% is classified as poor (Depdiknas, 2002). It shows that the comprehension of Indonesian students for probability material is in the poor category, so there is a need for improvement. MTs Negeri 3 Sleman is one of the schools with A accreditation located in Sleman Regency. Based on the results of the 2019 National Examination, students at MTs Negeri 3 Sleman in the probability material had an absorption power of 54.76% and 67.26% which were in the less category.

The topic of probabilistic is embedded in a cultural context (Naresh et al., 2014), the problem of opportunity is very close to students' lives. Students' mastery of probabilistic is to deal with uncertain situations, predict, decide between possibilities, deliberate action taking and develop thinking skills that are different from deterministic ones. In this way children gather experience for real-life situations, where it is necessary to decide the best option out of many every day. At the same time children must accept the fact that some events may not happen (HodnikČadež & Škrbec, 2011). It is important for students to understand the topic of opportunity, not only theoretical understanding but problems in the form of story problems that are close to life's problems.

Students will be able to solve math story questions that at least require accuracy in reading story questions and understand stories that are realized by identifying known and asked results, estimating solutions, and carrying out problem solving procedures (Raharjo et al., 2009). The number of competencies students need to master in solving story questions makes story questions quite difficult for most students (Budiyono, 2008). It is indicated by the finding of errors made by students when solving story questions. Four reasons why students have difficulty solving math problems in the form of stories, including 1) lack of motivation from within students to solve math questions in the form of stories, 2) lack of experience with the conditions and situations of the problems given and the lack of skills in processing the information provided, 3) math questions in the form of stories are irrelevant to students' life in the real world, and 4) students are not familiar with the language used in story questions (Awofala, 2017). Thus, it is necessary to analyze student errors in solving story questions to find the right solution to overcome student difficulties.

An analysis is an attempt to break down a problem or focus of study into parts (decomposition) so that the arrangement of the form of something that is described is clearly visible and, therefore, can be understood more clearly or the meaning is more clearly understood (Satori & Komariah, 2014). Student error is a matter that deviates from the established procedure when solving a problem. Thus, error analysis attempts to investigate an incorrect or deviant matter to find out the problem and its causes. Student errors can occur due to many factors; broadly, the factors that cause student errors are divided into general factors and certain factors (Askury, 2009). Common factors that cause errors made by students when working on story questions are internal factors and external factors. In contrast, certain factors are factors that specifically cause students to experience errors. Internal factors come from within students, including physiological factors, student ability factors, student learning factors, and interest and motivation factors. External factors come from outside the students, including the teacher and the social environment. The social environment close to students includes family, school, and community. Specific factors that cause students to make errors in solving probability material story questions can be in the form of students' inaccuracy, lack of mastery of the probability material, forgetting formulas, rushing, not checking answers again, or because they are not used to writing the final answer.

Errors are natural, but if they occur repeatedly and continuously, an error will negatively impact students. Thus, it is necessary to analyze student errors or investigate deviations made by students to identify problems and their causes by systematically identifying, classifying, and interpreting them (Legutko, 2008). Finding out the types and locations of students' errors in solving story questions can be analyzed using Newman's theorem of error analysis in the form of reading errors, comprehension errors, transformation errors, process skill errors and encoding errors (Clements & Ellerton, 1996; Jha, 2012). Errors in reading are not directly related to the ability to solve math problems (Wijaya et al., 2014). Therefore, errors made by students will be analyzed in terms of four aspects of Newman's revised errors, namely comprehension errors, transformation errors, process skill errors and encoding errors.

2. Method

The subjects in this study were 152 students of MTs Negeri 3 Sleman from 5 classes who had received material on empirical and theoretical probabilities in the even semester. The basic competency in probability material is explaining the empirical and theoretical probability of an event from an experiment, and solving problems related to the empirical and theoretical probability of an event from an experiment. Probability instructional was presented using the scientific method.

Formative tests were used to find students' errors in working on story questions, which can function as diagnostic tests (Decristan et al., 2015; Magno & Lizada, 2015). Diagnostic tests are tests to measure students' abilities and find out weaknesses or errors made by students so that, based on the results of the diagnostic test, appropriate solutions can be sought (Arikunto, 2012). Diagnostics is an action to properly analyze a problem and identify its causes to make decisions based on classification (Templin & Henson, 2010). According to the Ministry of National Education (2007), a diagnostic test is a test to determine student errors so that appropriate treatment can be given based on the diagnostic results. The main function of a diagnostic test is to identify errors experienced by students and plan follow-up actions in the form of efforts to deal with errors that occur (Khiyarunnisa, 2019).

The diagnostic test is in the form of a story about probability material which consists of 7 items, with indicators of questions; given a personal context, students can determine the sample space; given personal context, students can determine the relative frequency of an event; given personal context, students can determine the probability of an event; given personal context, students can determine the relative frequency of a compound event; given a personal context, students can show comparisons of empirical and theoretical probabilities; given a personal context, students can determine the value of the probability of a complement and frequency of expectations; give a personal context, students can determine the probability of a compound event. A rubric based on Newman revised theorem was used to identify errors made by students (see Table 1).

Meanwhile, to find out the causes of students' errors in solving the story questions of probability material made by students, a questionnaire was used. The questionnaire used in this study contained 23 positive statements divided into internal and external factors. Aspects of internal factors were in the form of physiological factors, student ability factors, student learning factors, and students' interest and motivation factors for mathematics. Meanwhile, aspects of internal factors in the form of teacher and student environmental factors include school, family, and community factors. The interpretation guideline that will be used to convert percentages into words is a five-scale interpretation guideline, according to (Widoyoko, 2009).

The validity of the instrument used content validity through judgement of 2 experts. The results of the diagnostic test instrument's content validity and the expert questionnaire showed that the questions were declared valid. Meanwhile, the diagnostic test on 61 junior high school students showed the reliability estimation with many odd items at middle cleavage, not the same as the Feldt formula, which was 0.701 with high qualifications. In comparison, the questionnaire test of 61 junior high school students showed the estimated reliability was 0.705 with high qualifications. (Guilford, 1956).

Table 1. The Rubric of Students' Error in Questions (Summarize from Alhassora et al., 2017; Clements & Ellerton, 1996; Jha, 2012)

Error Type	Indicators
Comprehension Errors	Students misunderstand the information in the question Students misunderstand the command questions Students misunderstand the terms, tables, or diagrams at the questions
Transformation Errors	Students are wrong in determining the formula that will be used to solve the problem Students are wrong in converting a problem into mathematical form Students incorrectly identify the mathematical operations used to solve problems
Process Skill Errors	The students are wrong in carrying out the problem-solving procedure Students are wrong in entering data into the formula to solve the problem Students are wrong in doing calculations The students do not complete the completion procedure
Encoding Errors	Students make error in writing or arranging sentences of irrelevant final answers Students do not write the final answer

3. Result and Discussion

3.1 Errors in Doing Story Questions

This study involved 152 junior high school students. Each student worked on seven questions that, in the end, resulted in 1064 student answer data. From the comprehensive data on student answers, there were 63 or 6% correct answers, 735 or 69% answers with errors, and 266 or 25% blank answers (see Table 2). Of the 735 students' answers who experienced errors, the types of errors were analyzed. Analysis of student errors used guidelines based on Newman's theory of errors: comprehension, transformation, process skill and encoding errors. Reading errors (reading errors) were not included because errors at the reading stage did not have a direct relationship with students' ability to understand the problem (Wijaya et al., 2014) and also because these errors could not be matched with the mathematical modelling stage or the process of solving mathematical problems (Khiyarunnisa, 2019).

The analysis results of 152 students result in 735 data on student answers. It was found that 826 errors spread over four types of errors based on Newman's revised theory: misunderstandings, transformation errors, process skill errors, and writing errors in the final answer, where one answer can contain more than one error type. The distribution of each error is presented in Table 3.

Table 2. The Result of Students Answer Analysis

Notation	Total	Percentage
Correct Answers	63	6%
Errors	735	69%
No Answer	266	25%
Total	**1064**	**100%**

Table 3. Number and Percentage of Errors

Error Types	Total	Percentage
Comprehension	296	36%
Transformation	357	43%
Process skills	120	15%
Encoding	53	6%
Total	**826**	**100%**

The number of misunderstandings is 36%, and students need help understanding. Here are examples of misunderstandings made by students. Figures 1 and 2 show that students make the same error in understanding the information on question number 2. Students wrote what they know as "first taking card 5, taking the second card king, taking the ace card". It should be "the first taking the card numbered a multiple of 5, taking the card both King or Jack cards if the first draw is not returned, and the third draw is aces if the cards in the first and second draws are returned." In Figure 1, it can be seen that students combine the possible cards in the first and second draws and then conclude with the third card. Meanwhile, in Figure 2, the students did not write down the answers. Based on the results of the interviews, students were in a hurry when they wrote down what they knew about the questions.

Students also did not know that writing five and multiples of 5 would affect solving the problem. Students were also less able to understand the information in the questions because students did not master the material on empirical and theoretical probabilities. In Figure 3, students make errors on question number 1. Students misunderstand the term "possibility". In question number 1, the possibility is the number of sample spaces, but students interpret it by probability. Therefore, the student's answer on completion of number 1 is incorrect. Based on the results of interviews, students think that the sample space equals probability. Therefore, in solving problem number 1, students look for probabilities from each available choice of clothing. It is because students do not master the material on empirical probabilities and theoretical probabilities.

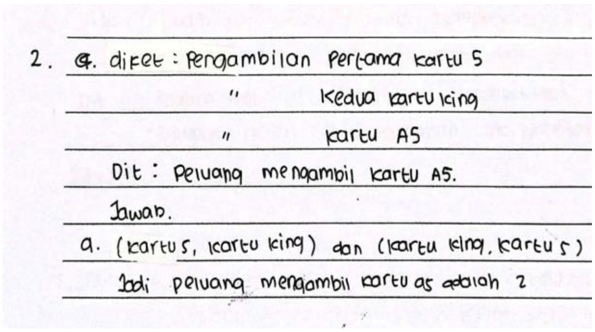

Figure 1. Errors' Student in Understanding the Information

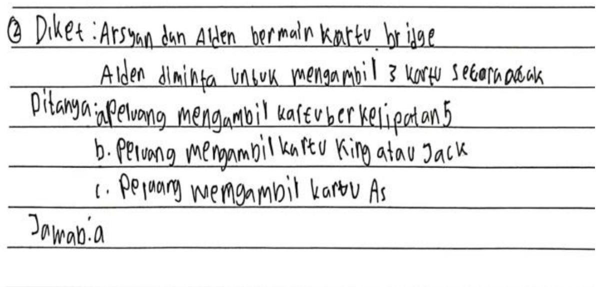

Figure 2. Students did not Write Down the Answers

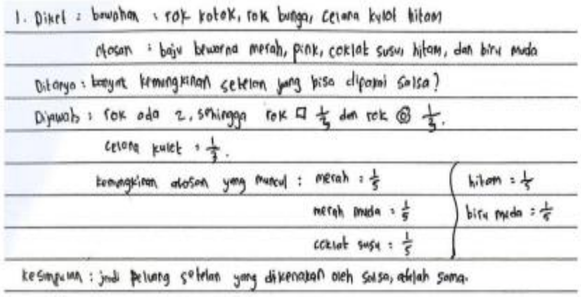

Figure 3. Students Misunderstand the Term "Possibility"

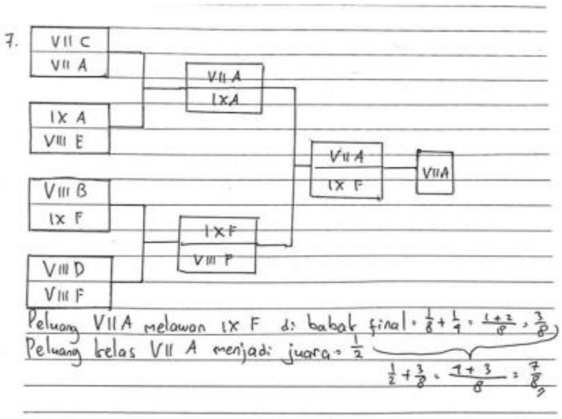

Figure 4. Students Made Transformation Errors

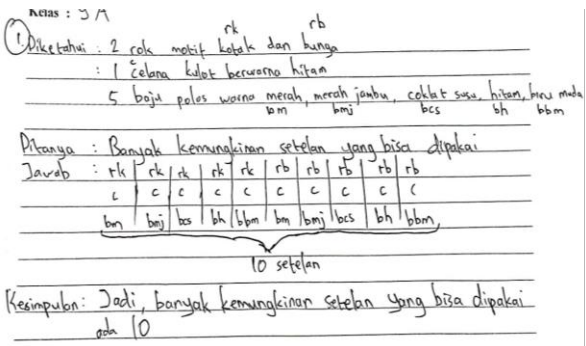

Figure 5. Errors' Student in Using Table for Identify Sample Space

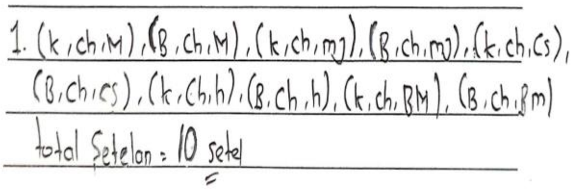

Figure 6. Errors' Student in Using Pair for Identify Sample Space

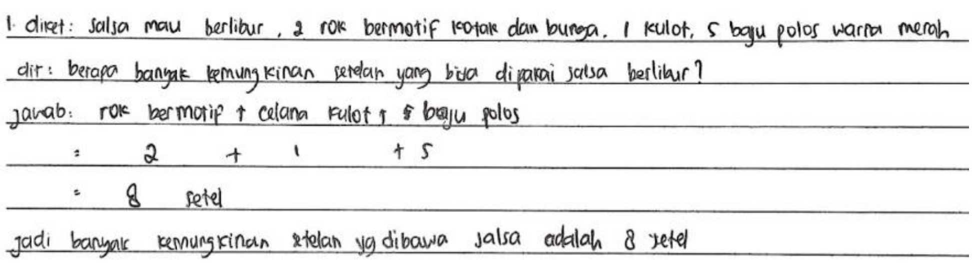

Figure 7. Students did not Know the Formula

43% of students made transformation errors. This result is in line with research conducted by Wijaya et al., 2014, which also uses errors, according to Newman, to analyze errors made by students, which is 42%. In Figure 4, students need help identifying the mathematical operations used to solve the problem number 7. Students use addition operations to solve problems when students should use multiplication operations. It makes the student's final answer incorrect. Based on the results of the interviews, students were hesitant to determine the correct addition or multiplication operation to solve problem number 7. Because of their haste, the students finally chose to use addition operations to solve the problem. In Figure 5, students try to find the number of pairs using a strategy using tables. However, because there are three components, they need help compiling them. Supposedly, the student can make the pants in its column in a row with a plaid skirt and a flower skirt. In Figure 6, students try to get the number of pairs using a tabulating strategy, but the tabulation needs to be completed. The student's error with this strategy is that pants should not be included in every member's mention but should be mentioned separately with the top clothes. Based on the interview results, students needed to be more careful because they thought the square skirt and flower skirt were headscarves that could be worn together with pants and shirts. Therefore, an error in converting a problem into a mathematical form makes the student's answer to question number 1 less precise. Meanwhile, Figure 7 shows students who need to learn the formula or strategy used to get the number of pairs of shirts and skirts or pants combinations. Based on interviews, students did not know what method could be used to solve problem number 1. Therefore, students choose to solve it by adding a total of "patterned skirts, culottes, and plain shirts". Students do not master the material on empirical and theoretical probabilities, so they do not know what strategies can be used to solve problems.

As many as 15% of students made process skills errors. In Figures 8 and 9, it can be seen that students made the same errors in doing calculations on question number 3. Figure 8 shows that students were wrong in calculating the addition of the calculation "(39 + 42 + 37) = 128". The result should be "118". In Figure 9, the student incorrectly added: "(42 + 37 + 43+ 39 + 37) = 202". The result should be "198". It makes students wrong in determining the value of "the dice that is more than 3" and the value of "x" to make the student's answer incorrect in the next procedure. Based on the interview results, students were less focused because they were in a hurry when calculating, so errors occurred when doing calculations. Students also did not have time to re-check their answers before they were collected, which made errors unavoidable. Therefore, the students made an error in the calculation of question number 3.

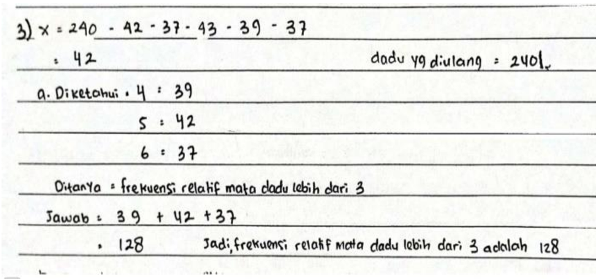

Figure 8. Error Student in Calculating

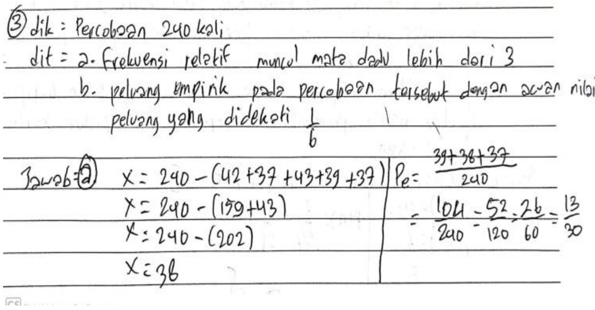

Figure 9. Error Student in Calculating

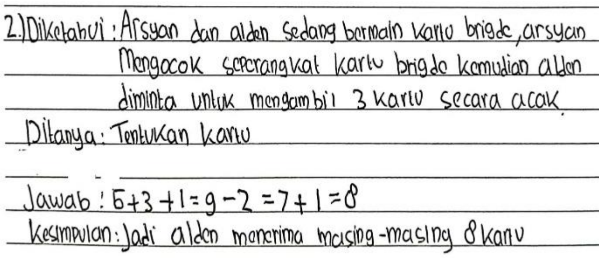

Figure 10. Error Student in Encoding

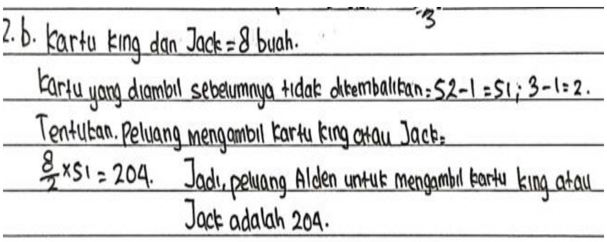

Figure 11. Error Student in Encoding

As many as 6% of students made errors in writing the final answer. Examples are presented in Figures 10 and 11. It can be seen that students made errors in writing or arranging sentences for irrelevant final answers. In question number 2, the question asked is the probability of drawing three cards, with each card having its criteria. In Figure 10, it can be seen that the student's final answer was, "So Alden received 8 cards each." The student's answer was not relevant to what was asked in the question. Therefore, the student's answer to question number 2 was incorrect. In Figure 11, it can be seen that the student's answer is, "So, the probability of Alden to take a King or Jack card is 204". The answer is irrelevant because the expected answer is a probability, while students answer it with "204", which is not the value of probability. Since the probability value is greater than or equal to 0 to less than or equal to 1, it can be written as $0 \leq P(A) \leq 1$. Based on the results of the interviews, students did not understand what was asked in the question, thus making students unable to write the final answer that was relevant to what was asked in the question. Students admitted that they lack mastery of empirical and theoretical probabilities.

3.2 Cause of Difficulty

Various factors caused students' difficulties in solving problems of empirical probability and theoretical probability. The specific factors that caused students to make errors in solving story questions were empirical probabilities and theoretical probabilities based on the results of interviews with students because students were not careful, were in a hurry, have difficulty understanding questions, did not master the material, did not understand what is being asked in the questions, forget formulas, hesitant to determine the formula, did not re-check the answer and was not used to writing the final answer/conclusion.

Common causes of students making errors are done through a questionnaire to find out the factors that cause students to make errors in solving story questions on the material of empirical probability and theoretical probability. The following results were obtained from 115 students who filled out the questionnaire.

Table 4. Internal Factor Results

Aspects	Percentage
Physiologic	84%
Learning Ability	62%
Learning Style	74%
Interests and Motivation	60%

Table 5. External Factor Results

Aspects	Percentage
Teacher	72%
Family	76%
School	80%
Society	64%

Based on Table 4, the physiological factors with a percentage of 84% are included in the good criteria, which can be interpreted that the physical condition of students in the form of sight and hearing when learning activities occur is in good condition. Therefore, it does not affect the errors made by students. The percentage of 62% that falls into the medium criteria is obtained on the student's ability factor. It means that the student's ability to master the material of empirical and theoretical probabilities are moderate. In this case, it means that students' ability is quite influential on the errors made by students. Then, on the factor of the student learning, a percentage of 74% is obtained, which is included in the good criteria. It can be interpreted that students already have a good learning style and feel easier to understand when studying with friends. It means that the way of learning could be more influential on the errors made by students. Furthermore, the last factor on internal factors, namely interest and motivation factors. It obtained a percentage of 60%, which was included in the moderate category. It can be interpreted that the interest and motivation of students in mathematics are moderate. It means that the interest and motivation of students are quite influential in the errors made by students. Thus, the internal factors that most influence students' errors in solving story questions on empirical and theoretical probabilities are interest and motivation factors. The student's ability factor follows the student's learning method and physiological factors.

Based on Table 5, the teacher factor with a percentage of 72% is in good criteria, which means that the personality, teaching style, learning method, learning approach, learning strategy, material provision and teacher motivation are good. Therefore, it does not affect the errors made by students. The percentage of 76% that falls into good criteria is obtained in the family factor. It means that learning facilities and infrastructure at home, family economic conditions, and parental concern for education are good. Therefore, it does not affect the errors made by students. Then, the school factor obtained a percentage of 80%, which is included in the good criteria. It can be interpreted as learning facilities and infrastructure in schools, atmosphere, laboratories, and school discipline are good. It means that the school could be more influential in the errors made by students. Furthermore, the last factor is the external factor, namely the community factor, with a percentage of 64%, which is in the moderate category. It can be interpreted that the behavior of the community in their environment is quite influential in the errors made by students. Thus, the external factors that most influence students' errors in solving story questions on empirical and theoretical probabilities are society factors, teachers, family, and school.

4. Conclusion

Based on the results and discussion, it can be concluded that the type of error that is mostly made by students in solving the story questions on the material of empirical probability and theoretical probability is transformation errors, which is 43%, comprehension errors (comprehension errors) of 36%, process skill errors of 15%. The last one is encoding errors of 6%.

Based on the results of interviews with 11 students, students' errors in solving story questions on empirical probability and theoretical probability are caused because students are not careful, students are in a hurry, students have difficulty understanding the problems at the questions, students did not master the material on empirical probabilities and theoretical probabilities, students did not understand what was being asked in the questions, students forgot the formula, students hesitated in determining the formula, students did not re-check the answers. Students were not accustomed to writing the final answer/conclusion. The general factors that cause students to have difficulty in solving story questions on empirical and theoretical probabilities were divided into two: internal and external factors. On internal factors, the most difficulty is influenced by factors of interest and motivation of students towards mathematics. Then, on external factors, the most influencing students' difficulties are society.

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