Analysis of Participants' Errors in Solving Mathematics Olympiad Problems

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Abstract. The purpose of this study is to provide support improving the HOTS of junior high school mathematics olympiad participants and analyze the errors made by participants in solving Mathematics Olympiad questions. The descriptive qualitative research approach explained the process of implementing the activities and students' answers to the Olympiad questions given. The obstacles faced by students during the preparation process such as: lack of time in completing practice questions, not reading the questions carefully, not being creative in answering questions, not being persistent in finding alternative solutions to problems, and unpolished analytical skills caused many students' answers to be found incorrect. The data collected were the participants' written answers.The data were analyzed descriptively through the following stages: 1) reading and reviewing the written answer data one by one to determine the errors experienced by students (reading), 2) making a brief description of the errors made by students (describing), and 3) grouping the errors made by students based on Newman Error Analysis reading, comprehension, transformation, process skills and encoding.

Keywords: Newman Error analysis; HOTS; Mathematics Olympiad

1 Introduction

The education system in Indonesia has undergone various changes including curriculum improvement to improve the quality of education [1], reorientation on improving students' higher order thinking skills (HOTS), especially in mathematics, to achieve improved quality of education[2].The quality of quality education as an indicator of the country's success needs to be monitored so that the quality can improve [3]. For a long time, the Mathematics Olympiad has been a competition that shows the ability of students with mathematical talent [4] in solving mathematical problems that require higher-level thinking skills. The Mathematics Olympiad is not only a prestige event for the participants, but also an important tool for schools and governments to assess the extent to which mathematics learning in schools has succeeded in improving students' HOTS abilities [4], [5], [6], [7], [8], [9]. These HOTS abilities, which include critical, logical, reflective, metacognitive, and creative thinking, are believed to be provisions in facing the development of the 21st century [10], [11], [12], [13], [14].

To measure students' mathematical thinking skills, the government and educational institutions will conduct a number of assessments. To assess students' thinking skills, the government organizes the National Science Olympiad through the Minister of Education

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(Kemdikbudristek). The best students from each province who have passed the district and provincial selection will participate in this competition. Every year, the competition is held in a different city. The selection process of students who will represent Indonesia in the international science olympiad depends on the National Science Olympiad results.

SMP Fransiskus Saverius Ruteng is one of the schools that participated in the 2023 Mathematics Olympiad and prepared for it by joining the competition at the district level, commonly known as the District Science Olympiad. The school has a vision and mission to improve the quality of education. Therefore, SMP Fransiskus Saverius Ruteng concentrates on mastering the material and improving the HOTS skills of its students. SMP Fransiskus Saverius Ruteng tries to improve the HOTS ability of its students by providing special assistance for students who are prepared to participate in National Science Olympiad. This preparation cannot be done in regular classes due to the diversity of students' abilities in mathematical skills and the different demands of questions that become standard learning in class and Olympic questions. Researchers are interested in providing assistance for additional preparation for the OSK to improve students' higher order thinking skills in addition to the assistance provided by the school. High-level thinking skills (HOTS) became the focus of the problem training due to the characteristics of Olympic questions that prioritize HOTS in the questions given. After that, the researchers analyzed the errors made by students in solving the 2023 Olympiad questions as evaluation material for the preparation class and training in the following period in preparation for the implementation of the preparation class in the next period.

Newman Error Analysis has 5 rules for analyzing error types. Newman's Error Analysis is based on five rules: reading, comprehension, transformation, process skills and encoding. These errors are usually caused by students' weak reading comprehension skills, lack of mastery of mathematical materials, students' inability to translate relevant information into mathematical equations, and lack of practice working on math problems that require higher-level thinking skills. Nevertheless, the math errors shown by students can be used as a reference by teachers to correct them. Teachers can use students' incorrect answers to guide students towards the correct answer without giving the correct answer beforehand. In addition, students who experience errors or fail to provide correct solutions in solving math story problems can learn better from their mistakes.

2 Method and Materials

This type of research uses qualitative descriptive research. Descriptive research is research conducted to determine the value of independent variables, either one or more variables (independent) without making comparisons, or connecting with other variables .

This research was attended by 7 best students at SMPK Santu Fransiskus Xaverius Ruteng, NTT who were prepared to take part in the National Science Olympiad in Mathematics. This research was carried out with the stages of preparation, implementation, evaluation, and report preparation which was carried out from January to July 2023. The research was conducted in a hybrid manner, in-network and out-of-network, taking into account the limited time of students but still paying attention to the quality of learning and active participation of students during the research process. Off-network research was conducted at SMPK Santu Fransiskus Xaverius Ruteng. The implementation of the research was carried out with a time allocation of approximately 2 x 45 minutes per meeting.

Observation activities were conducted to collect data about the research process, such as how students responded and how their thinking skills developed. The researcher participated directly in the observed phenomena and subjects. Documentation was also used to support the data obtained through other data collection methods. Documentation consisted of students' assignments and photographs of the activities that students performed during the research.

This research used the 2023 District Mathematics Olympiad questions and the students' written answers were collected for analysis. The main data collector in this study is the researcher. The researcher will act as a planner, implementer, collector, analyzer, interpreter, and reporter of the research results. The researcher analyzed the errors made by students in solving the Olympiad questions given.

3 Results and Discussion

This section will discuss the process of conducting the research, the obstacles faced by students during the research process, and the analysis of errors made by students when solving OSK 2023 questions.

The preparation class for the Olympiad is an important step in the effort to improve students' HOTS skills at SMPK Santu Fransiskus Xaverius Ruteng. This preparation class is relevant in the context of the 2023 Mathematics District Science Olympiad preparation for students in this school because: (1) focused on HOTS skills; (2) provided additional materials; (3) more individualized approach; (4) increased confidence; (5) collaboration with peers; (6) high motivation.

This preparatory class is conducted intensively, allowing researchers to focus on developing the HOTS skills of students who have been selected for the Olympiad. In regular classes, there is often limited time to train students in problem solving that requires higher order thinking due to the diversity of students' mathematical abilities in one class. In this preparatory class, students can get more intensive practice in dealing with typical Olympic problems that require higher-order thinking skills. The class is designed to accommodate additional material that is usually not covered in the school curriculum (e.g. the concept of divisibility). In addition, special techniques in mathematical problem solving that are usually required in solving Olympic problems were introduced. The smaller number of students allows researchers to give more individualized attention to each student. It is easier to identify student characteristics, students' initial mathematical abilities, weaknesses and strengths of each student. Thus, being able to provide guidance that suits individual needs. Hopefully, this will help students to more effectively prepare themselves for the Mathematics OSK. This preparation class is expected to increase students' confidence in working on problems, so that they are better prepared to face the questions given. Students are encouraged to collaborate with peers in solving math problems. This kind of discussion and collaboration helps students to develop their mathematical communication skills, which is also an important aspect of HOTS skills. High motivation to improve their math skills is expected to be more embedded after attending this preparation class. Students are expected to realize the value of this preparation as an opportunity to increase their chances of success in OSK Mathematics.

The obstacles faced by students during the preparation process such as: lack of time in completing practice problems, not being careful in reading problems, not being creative in answering problems, not being persistent in finding alternative solutions to problems, and unpolished analytical skills led to the discovery of many students' answers that were not correct.

On March 15, 2023, the preparatory class began by identifying students' initial ability to solve Olympic problems. This initial identification of math skills showed that students had good math skills. The problems were able to be done using structured mathematical procedures and were able to perform mathematical calculations correctly. However, students need to be accustomed to working on problems in a way that shows higher-order thinking skills and not just procedural.

Fig. 1. Process of learning.

Furthermore, the preparation class is held intensively online through Zoom Meeting. During this preparation process, students were given the opportunity to work on OSK questions from previous years. Before the meeting took place, the researcher distributed questions to be worked on and then discussed during the meeting. During the study, the researcher discussed the problems given in the OSK while explaining the material related to the problem being discussed. Among other things, algebraic identity, combinatorics, and problem solving strategies that are directly applied to the problems. Students are actively involved in the process of working on problems and convey how to solve problems with their respective versions. On May 16, 2023, students took part in the OSK selection and solved the problems given online.

Fig. 2. Students solve the olympiad questions.

When the preparatory class stage for the Olympiad was completed, students participated in the District Science Olympiad selection and completed the questions given. The researcher asked students to collect their answers to see how students worked on the problems and analyze what mistakes students made in solving the problems.

Students' answers will be analyzed using Newman’s Error Analysis. According to Newman's Error Category there are 5 classifications or criteria for errors in working on

problems, namely: reading, comprehension, transformation, process skills and encoding. Students that are in the reading stage can read the problem. At the understanding level, pupils are able to comprehend the issue. Students select a formula to solve the problem at the transformation step. Students may successfully complete and compute the problem at the process skills stage. Students are able to accurately articulate the problem's solution at the encoding stage. Students did not answer all the questions given. The researcher selected students' answers per category to see and explain the errors made by students in solving the problem. The following are some of the errors made by students and need to be considered in the next learning process.

1. Reading

   This type of error criterion explains errors where students solve problems with concepts that are not true, and students only immediately write answers without being accompanied by logical thinking but based on the possibilities of how the problem can be solved.

   One of the problems given:

   " The number of seven-digit natural numbers composed of 0 or 1 only and divisible by 6 is..."

   One of student's answe can be seen in Fig. 3.

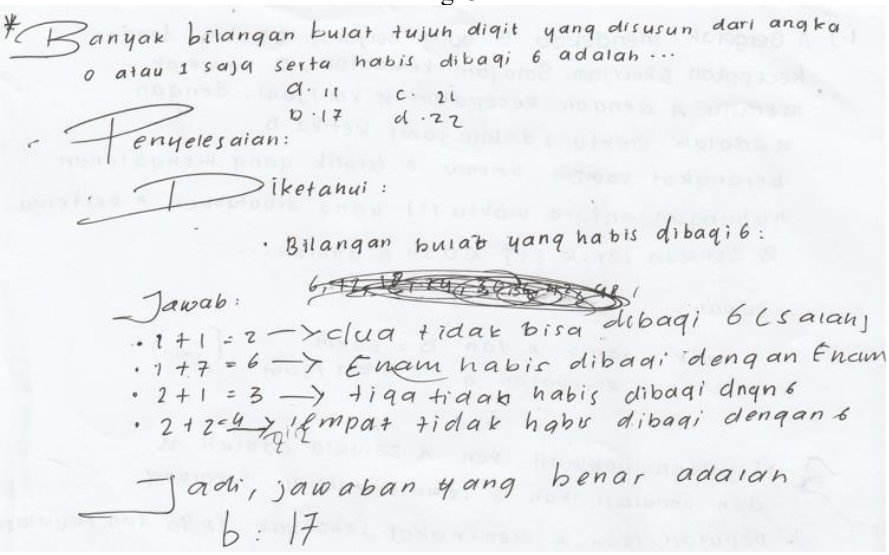


Fig. 3 Analysis of Answer 1

In the problem, students are asked to calculate the number of 7-digit numbers consisting of 0 and 1 and divisible by 6. Students do not utilize the information in the problem such as identifying the properties of numbers divisible by 6 (the possible unit is 0) and in order to be a 7-digit number, the first constituent number must be 1 (and not 0). In Fig. 3, it can be seen that students solve the problem by looking at the available answers, then checking whether the numbers available in the answer meet the criteria in the problem, which is divisible by 6 by previously summing and then dividing by 6. The concept of divisibility needs to be explained in more depth so that students are able to work on problems like this in the future.

2. Comprehension

In this stage, students are encouraged to understand the problem clearly.
One of the problems given:
" Aima gets a chance to have a free dinner at a restaurant from June 1 to 10, 2023. Aima may choose more than one arrival date during this period as long as they are not consecutive dates. If Aima plans to come at least once, then the number of possible arrival schedules that Aima can make is...."
One of student's answe can be seen in Fig. 3.

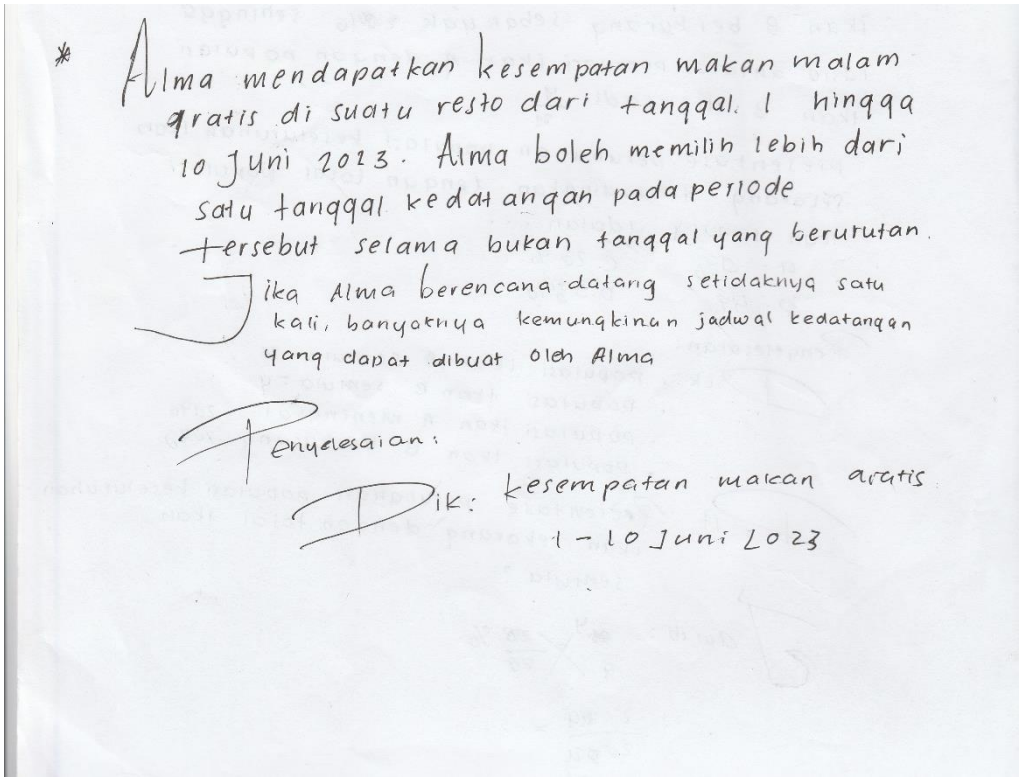
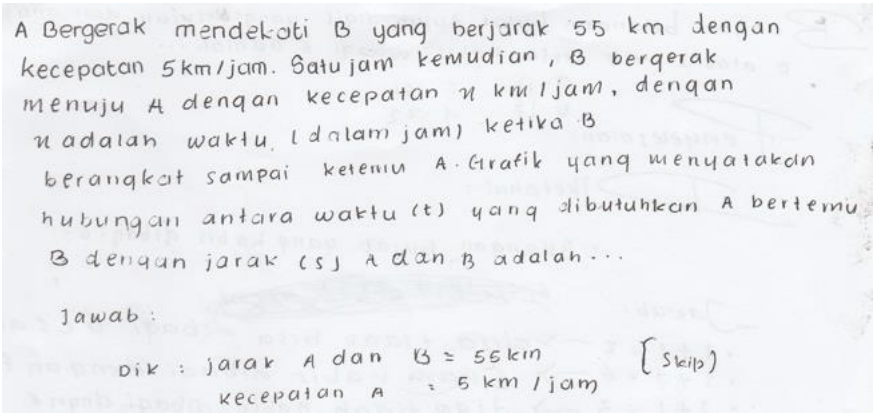


Fig. 4 Analysis of Answer 2

From the written answers in Fig. 4, it can be seen that students are unable to write and understand the information given in the problem. Students do not even make one of the possible schedules that arise by using the information given in the problem. Failure to understand the meaning of the problem makes it difficult for students to proceed to the next process, namely making possibilities that can occur and then making a pattern in determining the answer.

3. Transformation
Transformation stage requires student to choose the formula that can solve the test.
One of the problems given:
"A is moving toward B, which is 55 km away, at a speed of 5 km/h. One hour later B is moving towards A at x km/h, with x being the time (in hours) from when B sets off until it meets A. The graph representing the relationship between the time (t) it takes A to meet B and the distance (S) between A and B is...."


A Bergerak mendekati B yang berjarak 55 km dengan kecepatan 5 km/jam. Satu jam kemudian, B berqerak menuju A dengan kecepatan x km/jam, dengan x adalah waktu (dalam jam) ketika B berangkat sampai ketemu A. Grafik yang menyatakan hubungan antara waktu (t) yang dibutuhkan A bertemu B dengan jarak (s) A dan B adalah...

Jawab:

Dik : jarak A dan B = 55 km (Skip)
kecepatan A = 5 km/jam

Fig. 5 Analysis of Answer 3

In addition to the ability to understand the story problem given, by understanding the concepts of speed, distance, and time students are expected to be able to understand the graph given in the problem. However, students find it difficult to identify the right formula that can be used to answer the questions given.

4. Process skills

One common error is that students incorrectly perform algebraic operations such as adding, subtracting, dividing, and multiplying numbers. In Figure 3, it can be seen that students simplify fractions by crossing out q^2 in the numerator and denominator respectively. Of course, this kind of procedure is an error that illustrates students' inability to complete algebraic calculation operations.

One of the problems given:

"Consider the following two equations.

$$A = \frac{(p^2+q^2+r^2)^2}{p^2q^2+q^2r^2+p^2r^2} \text{ and } B = \frac{q^2-r^2}{p^2+q^2+r^2}$$

If $p+q+r=0$ then the value of $A^2-4B=\cdots$"

One of the students' answers can be seen in Fig. 6.

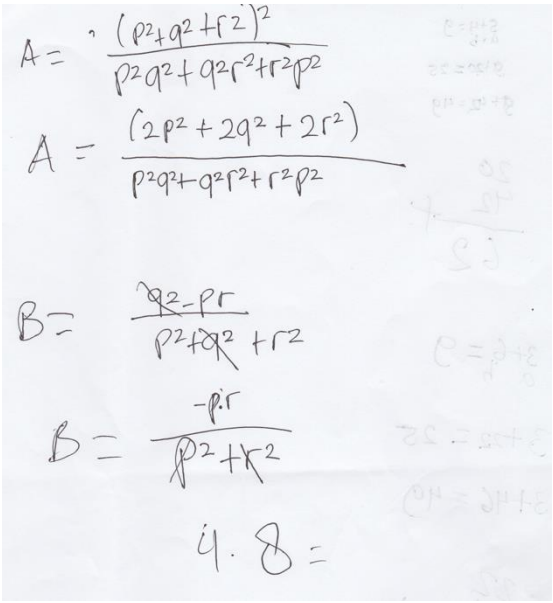


Fig. 6 Analysis of Answer 4

Based on Fig. 6, it can be seen that they failed to simplify the fraction. Students immediately simplify just because there is the same term. Errors in understanding the concept of fractions and simplifying fractions are errors that are often encountered. Students need to be informed in more detail about the reasons for simplifying fractions and how to do it correctly.

5. Encoding stage

This error occurs where the student stops solving the problem before reaching the last stage. Students are supposed to explain the solution of the problem correctly. Here we can see how students try to solve the problem by trial and error. However, students have stopped before obtaining the correct answer. This trial and error process requires strategy and persistence in order to arrive at the correct answer.

One of the problems given:

"Given a, b, c, d, e are positive integers that satisfy $a \leq b \leq c \leq d \leq e$ and $a + b + c + d + e = abcde$. The largest possible value of e is..."

One of the students' answers can be seen in Fig. 7.

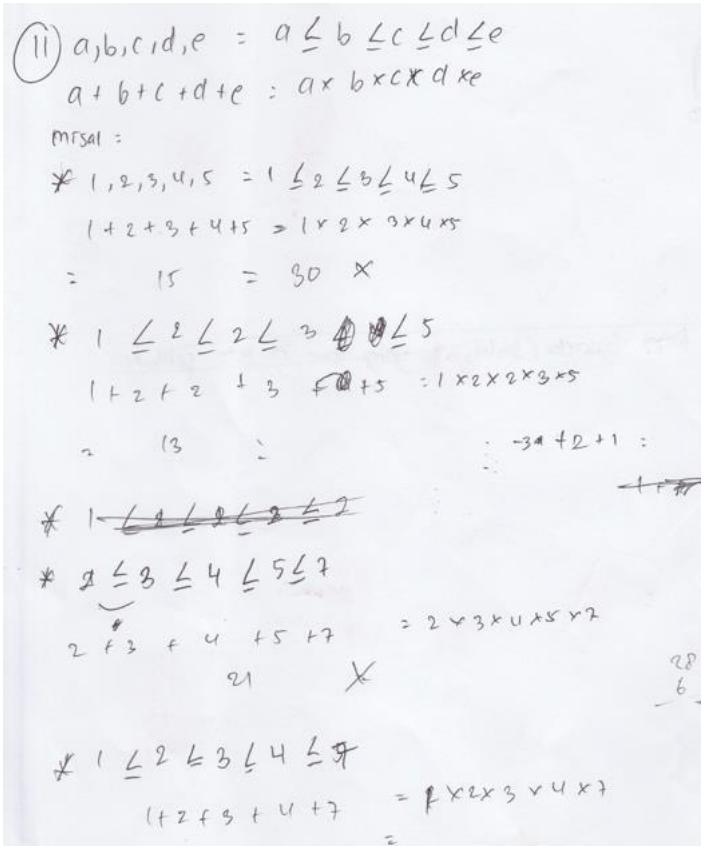


Fig. 7 Analysis of Answer 5

One strategy that students can use to solve problems like the one above is to first do trial and error. After the trial and error process is carried out, it is hoped that students will be able to find a pattern to solve the problem. However, In Fig. 7 we saw students stop when the solution is still not found. The learning process that emphasizes the process of finding answers needs to be done regularly. Students need to learn that finding a solution requires a process that is not instantaneous. It takes perseverance and creativity in the process.

However, it is realized that this preparation class has not been carried out optimally in terms of time and intensity of implementation. Analysis of students' responses suggests that more continuous and structured activities are needed to truly prepare students for the OSK and other higher level Olympiads.

4 Conclusion

The math Olympiad uses problems that are very new and usually unprecedented. Solving Olympic problems requires high-level thinking skills to solve them. In order for this to be achieved, higher-order thinking habits must be trained through more intensive and structured problem exercises in terms of material, especially those related to math olympiad problems. During the early stages of learning, students should receive support before they can practice independently. However, it is important to remember that too much or too little support can

hinder progress in higher order thinking skills. Olympic problem solving requires support from others who are proficient in Olympic math and self-discipline.

Students face problems such as not preparing for the test, reading the questions inaccurately, answering in uncreative ways, lack of patience, and lack of analysis. This olympiad activity is conducted in a hybrid manner both online and offline. One of the problems faced by researchers when assisting students is the shorter guidance time. To participate in the Mathematics National Science Olympiad in junior high school, students must be trained in reading carefully and critically, trained to be diligent and persistent in solving problems, and trained in mathematical reasoning and creativity. In addition, students should get intensive support to familiarize themselves with non-routine problems.

The results show that classroom activities to prepare for math olympiads should be done better, involve people who are more proficient in math olympiads, and by paying attention to the error analysis that has been done. In addition, similar activities should be implemented at lower levels of education in primary schools in Manggarai, East Nusa Tenggara.

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