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Analysis of students' mistakes in solving mathematics olympiad problems

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Abstract. This study aims at analysing students' mistakes in solving mathematical olympiad problems. The test was conducted in SMA Negeri 1 Palembang involving 40 students. The main topics are algebra, combinatorics, geometry, and number theory. The analysis is based on Newman Error Analysis. The results show that the most common mistakes are found in combinatorics and geometry. The most common mistakes analysed using Newman Error are comprehension and transformation errors. In order to solve this problem, teachers need to assign various mathematical problems. Hence, the students will have more flexibility to apply problem-solving strategies.

1. Introduction

The study begins because when someone wins the olympiad, they can improve the prestige of their school [1 - 4]. That's why most of the schools try their best to send their students' representation to win the olympiad. The Ministry of Education and Cultural is supporting the olympiad by making National Science Olympiad (OSN) [3 - 6]. The number of participants in the OSN is increasing every year [7]. The Government has already facilitating students that like mathematics by holding OSN since 2003 at the national level [3, 5, 6]. OSN aims to find the exceeded students that found in cities and region all over Indonesia to be prepared participated International Mathematics Olympiad (IMO) in international level [3, 7, 8].

Winning the selection of OSN is not an easy task because the participants must pass all the selection from 3 levels in city, province, and nation level [7, 9]. For this reason, a thorough preparation is required before entering the competition due to strict selection. The topic in OSN is general, but the problems require participants to answer with a high level of thinking. The different way of thinking from solving common problems are needed, these are the issues that need to be solved [10, 11].

OSN Syllabus refers to aspects of reasoning, problem solving, and mathematical communication [9]. Mathematics is the science of logic regarding the structure, quantity, and concepts related to one another [12, 13]. The mistakes that occur where people have different logics and structuring concepts of mathematics because when learning mathematics everyone has differences in understanding, knowledge, and other aspect of the environment [13, 14]. According to other researchers, aspects that needed in solving OSN problems are the maturity of mathematics with advanced levels such as concepts, comprehension, accuracy, foresight, ingenuity, ways of thinking and mathematical experience [15, 16]. Syllabus from OSN refers to the International Mathematics Olympiad (IMO) and can be classified into four main topics namely algebra, combinatorics, geometry, and number theory [8, 17].

Studies suggest that experiences are various because students have different comprehension and knowledge from each other [15, 18 - 20]. This can be an obstacle in learning if the roots of problems are



founded. For this reason, tests will be conducted and students' answers will be analyzed following the procedure of Newman Error Analysis. This analysis consists of (1) reading error (error type 1) is caused when the students cannot read, in common cannot understand the terms, words, and symbols used in the problem, (2) comprehension error (error type 2) is caused when the students do not understand the main idea of the problems and cannot determine what is known and what is being asked, (3) transformation error (error Type 3) is caused when the students fail to specify the formula or strategies or procedures, (4) process skill error (error type 4) is caused when fails to work and not using appropriate algorithm, and (5) encoding error (error type 5) is caused when the students are not able to answer according to what being asked [10, 11, 14, 21 - 25].

Sumatera Selatan is one of the provinces actively taking part in OSN because Education Authorities in Palembang wants to show their region's potential [5]. SMA Negeri 1 Palembang is one of the schools that takes part in OSN every year and also actively conducts training for students. They support all of the students that elected by school because superior in academic. In this case, mathematics is the focus of the researcher, because we are the instructor of mathematics' olympiad. The research was conducted there and the results were analysed using Newman Error Analysis. The tests will be divided into four main topics that have already mentioned.

It is hoped that from this research, we can see further which part should be improved. We hope to find the obstacles, so we can fix the most common mistakes that happen in students [14, 15, 26]. Eventually, we can learn what is needed hence we can improve their concepts and intensify the quality of learning [27]. In the future, we can focus on fixing the one that needed and improving their strategy to solve mathematical olympiad problems.

2. Method

The study is an analysis of mistake based on Newman Error Analysis. The research was conducted on students' in the olympiad class on SMA Negeri 1 Palembang. The subjects consisted of 40 students in grades 10 and 11. The tests will be carried out within 4 weeks. Each week, they will be given tests with different materials, namely algebra, combinatorics, number theory, and geometry constructively. Later on, each material will be given 2 questions each within 30 minutes.

Afterward, from each material, these mistakes will later be analysed. From the mistakes, we will evaluate the students' common mistakes that happen when solving the problems [20, 27]. The data will be grouped based on the mistakes that shown when they doing the test when doing algebra, combinatorics, number theory, and geometry. The tests will be analysed based on Newman Error Analysis that has been mentioned before.

3. Result and Discussion

This research consists of three stages, namely the preparation phase, the implementation phase, and the analysis phase. In the preparation stage, researchers determine the topics to be tested, search and select questions for tested based on the criteria of the questions that often arise in the Math Olympics and the difficulty level of the questions, make possible answers and the assessment rubrics, then design the implementation.

At the implementation stage, researchers conduct data retrieval with a written test. The implementation is carried out for 4 weeks, starting on August 24th, 2019 until September 14th, 2019. Details of the activities during the implementation process can be seen in Table 1.

Table 1. Implementation of taking test value.

No	Date	Topic
1	August 24 th , 2019	Algebra
2	August 31 st , 2019	Theory of Numbers
3	September 7 th , 2019	Probability and Combinatorics
4	September 14 th , 2019	Geometry

The implementation is carried out for 2 hours every Saturday with the activities carried out namely, 1 hour 15 minutes the first delivery of material conducted by the Olympic teacher, the next 30 minutes the students work on the Olympic questions consisting of 2 questions, and the last 15 minutes the students and the teacher discuss the questions that were tested.

In the data analysis stage, the researcher analyses the mistakes made by the research subjects through the results of student test answers. At this stage, the researcher analyses the students' errors based on the Newman error procedure which consists of reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors. The answers of students who experienced errors were analysed according to the descriptors of each Newman procedure that have been described in Table 2.

Table 2. Indicator of students error.

No.	Newman Procedure	Indicator
1.	Reading the problem (Reading)	a. Students can read or recognize symbols or keywords in question b. Students interpret the meaning of every word, term or symbols in the matter
2.	Comprehension the problem (Comprehension)	a. Students understand what is known b. Students understand what is being asked
3.	Transformation the problem (Transformation)	a. Students know what formulas will be used to solve the problem b. Students know the counting operation that will be used c. Students can create a mathematical model of the problem presented
4.	Process Skill	a. Student know the procedure or steps that will be used to solve the problem b. Students can explain the procedure or steps used to solve problem c. Students can find the final result according to the procedure or the steps used to solve the problem
5.	Writing of the final Answer (Encoding)	a. The student can show the final answer of the problem solving b. Students can write the final answer in a accordance with the conclusion in question

(source: Jha [21] and Singh [23])

Based on the analysis of students' answers, students make mistakes on almost all questions. Out of the 4 topics and each topic consists of 2 questions given, the most common error is the transformation error. Table 3 shows the percentage of mistakes made by students.

Table 3. Percentage of errors made by students based on Newman Error.

Category of Newman Error	Topic								Average	
	Geometry		Algebra		Theory of Numbers		Probability and Combinatorics			
	1	2	1	2	1	2	1	2		
Reading Error	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Comprehension Error	28%	11%	24%	27%	0%	31%	0%	0%	0%	15%
Transformation Error	39%	83%	29%	36%	0%	13%	100%	95%	49%	49%
Process Skill Error	6%	6%	24%	7%	25%	25%	0%	0%	0%	12%
Encoding Skill Error	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

3.1. Comprehension Error

Errors in the understanding phase (comprehension error) occur when students cannot understand the given problem. Based on table 1 above, as many as 15% of students make comprehension errors. There are two kinds of mistakes made by students, namely students are wrong in understanding what is known by the problem and students are wrong in interpreting what is desired by the problem. Figure 1 and Figure 2 below show the comprehension error made by students on the topic of algebra and geometry.

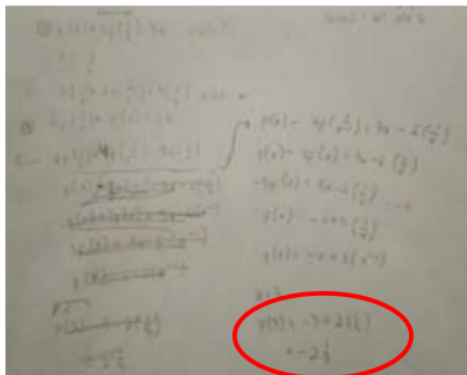


Figure 1. Student answers on algebra topics that show comprehension error

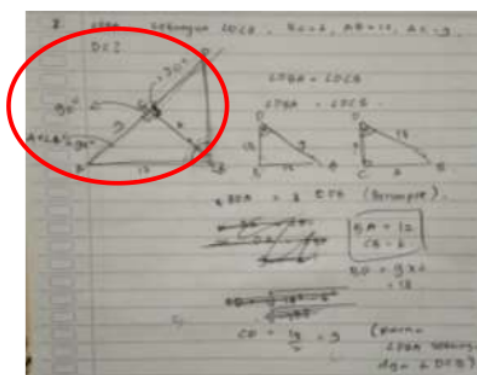


Figure 2. Student answers on geometry topics that show comprehension error

Based on the answers in Figure 1, students cannot understand the overall meaning of the problem, in this case the students are wrong in interpreting what the question wants. Students' answers in Figure 1 above show that students look for the value of $f(3)$. However, what is desired from the problem is to find the value of $f(x)$. According to [21] the error occurred because students did not understand what was asked by the problem or students incorrectly captured the information contained in the problem he could not solve the problem correctly. While in Figure 2, students misunderstood the picture given to the problem. Learners assume that $\angle BCE$ and $\angle BCA$ in the picture are right angles. Even though this is not known from the questions and $\angle BCE$ and $\angle CABCA$ are not right angles. This is because the teacher usually gives questions with right-angled triangles, so students are also accustomed to thinking that images in the problem are also elbow-shaped-elbow. The teacher only gives structured questions so that when given questions unstructured students' way of thinking is not developed [28].

3.2. Transformation Error

Error of transformation occur when students are able to understand the questions from a given problem but students have not been able to change the questions into mathematical form correctly or students fail to choose the right mathematical strategy to solve the problem. Based on table 1 above, transformation error becomes the mistake made by students with the highest percentage of 49% and the largest percentage of transformation errors that occur is on the Geometry topic number 2 that is 83% and the topic of probability and combinatorics about number 1 is 100%. Figure 3 and Figure 4 show successive transformation errors made by students on the topic of geometry and opportunity & combinatorics.

Based on the answers in Figure 3, students have not been able to change questions into mathematical form correctly, in these questions students incorrectly interpret a triangle shape into two similar triangles. The students' answers written in Figure 3 indicate that students already understand that $\triangle DBA \sim \triangle DBC$ as is well known in the problem, but the student made a wrong comparison of the two triangles, he wrote that $\frac{BC}{AB} = \frac{CD}{AD}$, while the correct ratio was $\frac{AB}{CB} = \frac{DB}{DC} = \frac{AD}{AB}$. According to [22] transformation errors occur when students have understood the question requirements but fail in identifying the right mathematical operations to successfully solve the problem. Meanwhile, according to [29] transformation errors that often occur in geometry material are due to students difficulty in visual-spatial abilities, namely

difficulty in understanding geometric shapes, resulting in a lack of students' ability to manipulate geometric shapes.

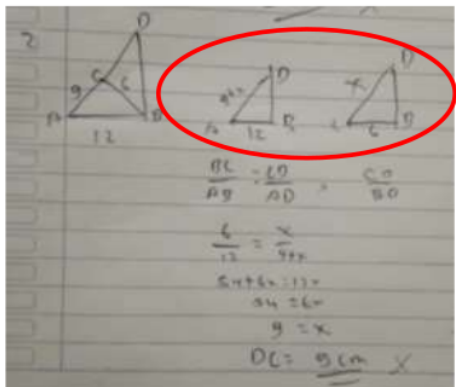


Figure 3. Student answers on Geometry topic which shows transformation error

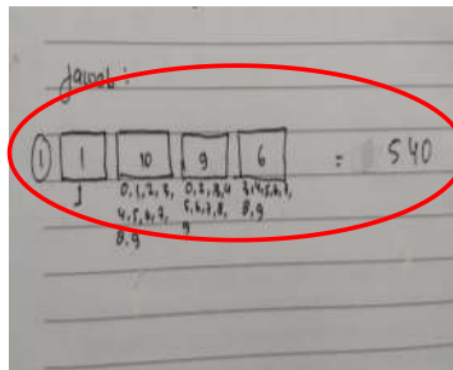


Figure 4 Student answers on topic of opportunity and combinatorics that show transformation error

Whereas in Figure 4, students fail to choose the right mathematical strategy, so students cannot solve problems correctly. The students' answers in Figure 4 for problem number 1 regarding probability and combinatorics show that students only make 1 case in the problem, students do not think about other cases that might occur. This is supported by the results of interviews with these students. During the interview, students revealed that the second number he wrote was 10, meaning that he could enter all the numbers because there was a condition that there were two numbers that were the same. In box 3 he writes 9 because he thinks that one of the numbers has entered the second box, he explains that because there are two numbers that are the same and number 1 has been used for the second box then in the box when only nine numbers are left unused. In this step, students do not think that what if number 1 does not appear in the second box, because in the second box there are ten numbers that might appear. As for the fourth box, according to the results of interviews with students, he wrote 6 because the numbers 0, 1, and 2 have appeared in boxes 2 and 3. In this step, students also do not think that other numbers besides 0, 1, 2 can also be appears in boxes 2 and 3. At the interview also students realize that they have written the wrong number in the fourth box, because according to students the number that may appear in the fourth box is 3, 4, 5, 6, 7, 8, 9 he should write 7 possible numbers, but he was not careful enough to write only 6, so the final results he got were not quite right. In Figure 4, students make a mistake of transformation, which is supposed to solve the problem, it is not enough with just one case, to solve the problem it takes 3 cases so that it can cover all possible numbers that can be arranged. According to [30] the problem that often arises when students solve problems regarding combinatorics is that students cannot always consider all the possibilities that can be arranged according to the rules correctly.

3.3. Process Skill Error

Process skill errors occur when students have been able to choose operations or determine the strategies needed to solve the problem but are unable to carry out procedures correctly or experience errors in the mathematical calculation process. Based on table 1 above, as many as 12% of students make a process skill error. Figure 5 and Figure 6 show the process skill errors made by students on the topic of number theory.

Based on students' answers in Figure 5, students are able to choose the right mathematical strategy to solve the problem, but he made a mistake when doing the addition operation of $1,002,001 + 1,004,004$, he wrote the result is 1,006,005, while the answer that should is 2,006,005. This is in accordance with

the opinion of [23] that mistakes in process skills occur when students do not carry out mathematical operations correctly.

1.) jika a dan b bil-bul sedemikian sehingga $a^2 - b^2 = 2003$
maka berapakah nilai dari $a^2 + b^2$...

2.) m dan n adalah bil-bul yg memenuhi $m^2 + 3m^2n^2 = 30n^2 + 517$ Nilai $3m^2n^2$ adalah ...

1.) $a^2 - b^2 = 2003$
 $(a-b)(a+b) = 2003$
 $(a-b)(a+b) = 1 \times 2003$
 $(a-b) = 1$
 $(a+b) = 2003$ $\begin{cases} a = 1001 \\ b = 1002 \end{cases}$

$a^2 + b^2$
 $> 1001^2 + 1002^2$
 $= 1002001 + 1004004$
 $= 1006005$

Figure 5. Student answers on the topic of theory of number showing errors in mathematical operations

Likewise with Figure 6, the student has chosen the right mathematical strategy, but he did not continue the procedure or the working steps. The student only tries factor 507 is 1 and 507, but he does not try again for other factors 507 namely 3 and 169 and 13 and 39, if he tries with another 507 factor, he will find the right answer for the problem Based on research conducted by [31], one of the process skill errors occurs when the student does not continue the procedure or steps to complete it so that the student does not find the right solution.

2. m dan n adalah bil-bul yang memenuhi $m^2 + 3m^2n^2 = 30n^2 + 517$. Nilai dari $3m^2n^2$ adalah

$m^2 + 3m^2n^2 = 30n^2 + 517$
 $3m^2n^2 - 30n^2 + m^2 = 517$
 $(m^2 - 10)(3n^2 + 1) = 517$
 $(m^2 - 10)(3n^2 + 1) = 507$ ✓

$m^2 - 10 = 1$
 $m^2 = 11$
 $3n^2 + 1 = 507$
 $3n^2 = 506$
 $n^2 = \frac{506}{3}$

$3m^2n^2$
 $3 \cdot 11 \cdot \frac{506}{3} =$
 $11 \cdot 506 = 5566$

Figure 6. Student answers on the topic of theory of number, students do not continue mathematical procedures

13 Conclusion

Based on the results of the research and analysis above, it can be concluded that there are three things that high school students do when solving Olympic questions based on the type of Newman error with algebraic topics, number theory, probability and combinatorics. These errors are comprehension error (15%), transformation error (49), and process skill error (12%). The biggest percentage of error is transformation error. The error occurs because students have not been able to convert the questions into mathematics correctly and students fail to choose the right mathematical strategy to solve the problem.

5. Acknowledgments

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