How to Cite
Irawan, I. P. E., Suharta, I. G. P., & Suparta, I. N. (2018). Contribution of prior knowledge, appreciation of mathematics and logical-mathematical intelligence to the ability of solving mathematical problems. *International Journal of Physics & Mathematics*, *1*(1), 21-28. https://doi.org/10.31295/ijpm.v1n1.40

Contribution of Prior Knowledge, Appreciation of Mathematics and Logical-Mathematical Intelligence to the Ability of Solving Mathematical Problems

I Putu Eka Irawan
Universitas Pendidikan Ganesha, Singaraja, Indonesia.
Corresponding author email: eka.irawan@pasca.undiksha.ac.id

I Gusti Putu Suharta
Universitas Pendidikan Ganesha, Singaraja, Indonesia

I Nengah Suparta
Universitas Pendidikan Ganesha, Singaraja, Indonesia

Abstract---*The objectives of this research were to figure out the contribution of prior knowledge, appreciation of mathematics and logical-mathematical intelligence toward the ability to solve mathematical problems as well as to explore the errors made by students in solving mathematical problems concerning polyhedron. The population of this research consisted of 3,583 students of grade IX of all state middle schools across over Denpasar City. The sampling technique we used was a stratified cluster random sampling technique with samples number of 553 students. The type of this research is ex-post facto research with path analysis technique. The data were collected by using questionnaires and carrying out a mathematical ability test. Furthermore, the kinds of students answers on the ability to solve mathematical problems were analyzed to study the errors made by the students. The results of the research show two regression relationships, namely* $X3 = 0.523X1 + 0.636X2 + 0.506\varepsilon 3$ *and* $Y = 0.640X1 + 0.264X2 + 0.280X3 + 0.311\varepsilon Y$*. The first regression relationship indicates that (1) the contribution of mathematical appreciation towards prior knowledge is of 52.3 percent, and (2) the contribution of logical-mathematical intelligence towards prior knowledge is of 63.3 percent. Whereas the second regression relationship describes that (1) the direct contribution of mathematical appreciation towards the ability of solving mathematical problems is of 64 percent, and the indirect contribution is of 14.6 percent, (2) the direct contribution of logical-mathematical intelligence to the ability of solving mathematical problems was is of 26.4 percent, and the indirect contribution is of 17.8 percent, (3) the direct contribution of prior knowledge towards the ability solving mathematical problems is of 28 percent, (4) the mathematical appreciation and logical-mathematical intelligence contributed simultaneously towards prior knowledge is of 74.4 percent, (5) the mathematical appreciation, logical-mathematical intelligence, and prior knowledge contributed simultaneously towards the ability to solve mathematical problems is 90.3 percent. Furthermore, based on the analysis of students answers in mathematical ability test showed that the students still made errors in the concept of prior knowledge, in interpreting questions and weaknesses in arithmetic skills related to logical-mathematical intelligence.*

Keywords---*ability to solve mathematical problems, logical-mathematical intelligence, mathematics appreciation, prior knowledge,*

ISSN 2632-9417
Received Jan 10, 2018 / Accepted Jun 20, 2018 / Published Jul 05, 2018

Introduction

Mathematics is an essential subject to support other sciences. The aims of teaching mathematics are to enable students to understand mathematical concepts accurately and correctly and have the disposition of appreciating the use of mathematics in the daily life.

One of the main objectives of mathematics education, as specified in NCTM, Regulation of the Minister of National Education and Regulation of the Minister of Education and Culture, is to enable students to have the ability to solve mathematical problems. Problem-solving is an activity that uses students' knowledge and skills to solve irregular problems. The purpose of solving mathematical problems is not only to find an answer but also to construct all possibilities of logical and reasonable solutions. Mathematical problems are distinguished into two, namely closed problem and open problem. The presentation of mathematical problems in the forms of the closed problem (or highly structured problem) is formulating a mathematical problem in such a way that it only has one correct answer with one solution (Sudiarta *et al.*, 2007). The conceptual open-ended problem in the mathematical learning is a mathematical problem that is formulated in such a way that it has some, even many, correct solutions and many ways to reach those solutions. According to Schoenfeld (1997), this process provides students with an opportunity to "experience in finding something new in the process" (Sudiarta, 2006). According to Polya, the problem-solving process consists of four stages, namely (1) understanding the problem, (2) planning the solution, (3) solving the problem, and (4) rechecking (Sudiarta, 2013).

The results of the survey in two periods of Programme for International Student Assessments (PISA) in 2012 and 2015 show that for mathematical ability, Indonesia was among the bottommost ranks, namely 64th out of 65 countries in the world with an average score of 375, and ranked 69th out of 76 sample countries (OECD, 2014). This is in line with the results of the Trend International Mathematics an Science Study or TIMSS survey (2015) that placed Indonesia at the 35th position out of 49 countries. The mathematical questions in the PISA and TIMSS studies do not only measure the standard technical ability merely related to memory and calculation but also the abilities of reasoning, problem-solving, and forming argumentations.

If the students' ability in mathematics is low, five objectives of mathematics learning skill standards in NCTM cannot be achieved optimally. One of the standards that cannot be achieved optimally is the ability to solve mathematical problems. The problem-solving ability as one of the objectives of mathematical education still requires some improvement. Based on the observation, some students were still found to have weak ability to solve mathematical problems.

The ability to solve mathematical problems is extremely important and has a significant role in human life. The thinking skill and ability gained when a person solves a problem are believed to be transferable/usable by that person when facing a problem in his or her everyday life (Sudiarta, 2013). Therefore, the improvement of the ability to solve mathematical problems is extremely important in order to produce human resources that are strong and capable of facing the challenges in the forms of problems in their life. However, to improve the ability to solve mathematical problems, there are many factors involved. The effort made for the time being is more focused on students' external factors and little effort is focused on the improvement of the students' internal aspects. An example of students' internal aspect is their involvement in the learning process in the classroom. If the students are actively engaged in the learning process having been designed, the objectives of education are subsequently achieved too. However, in reality, students tend to be inactively engaged in the classroom. Such problem arises due to the lack of appreciation of mathematics in the students' selves.

Appreciation of mathematics is the tendency of students to view, assess and define mathematics as something to be mastered and something useful, and to believe that it will be useful for them if they study mathematics seriously (Suryani, 2015). Students with a low appreciation of mathematics tend to be inactively engaged in the learning process. This will cause the students to be able to construct their own knowledge in understanding the mathematical materials. In this case, appreciation of mathematics gives the students motivation, spirit and confidence that they will be able to understand the mathematical materials and that they have the ability to solve mathematical problems.

In addition to the appreciation of mathematics, the other internal factors that may influence the ability to solve mathematical problems are prior knowledge and logical-mathematical intelligence.

Prior knowledge is something that students need in the learning activities. Concepts in mathematics are arranged in a hierarchy, and in a structured and systematic manner, starting from the simplest concepts to the most complex concepts. This requires the students to understand and master the prior knowledge before learning the following materials (Hasratuddin, 2014). Most teachers tend to directly explain the main materials without taking into account the prior knowledge of the students. If the students are unable to master the prior knowledge well, it will be extremely difficult for them to understand the main materials. Thus, students will find it very hard to solve the problems related to the main materials.

Another internal factor assumed to have an effect on the ability to solve mathematical problems is the logical-mathematical intelligence. Logical-mathematical intelligence is one's capacity to think logically in solving problems and conducting mathematical calculation. A child who has such intelligence has a good ability in finding a relationship between the information having been obtained and the problems he or she encounters. This is in line with the problem-solving stages, namely the stages of understanding the problem and planning the solution. In the stage of understanding the problem, students must find and relate the information existing in the problem. Then, in the stage of planning the solution, the students must be able to relate the information obtained with the correct method or way of solving the problem. Therefore, students who lack logical-mathematical intelligence will not gain any clue from the information existing in the problem. Consequently, such students are bound to fail in solving the problem.

On the middle school educational level, the polyhedral aspects learned are surface area and volume of solid figures. Some of the errors frequently made by students in solving questions regarding solid figures are the errors in the calculation and the errors in using formulae. This is because students only memorize the formulae without understanding them. As a result, if the students are given a problem whose concept has a slight difference from the example, they will fail to solve the problem. In this case, the teacher must recognize the students' ability in order to find a way to help the students understand and solve the mathematical problems related to a polyhedron.

The materials of solid figures will be very useful in the construction planning, for example when constructing a house. When constructing a house, the area of the house, the shape of the house as well as the materials of the house must be well-planned against the budget that they have in order to maximize the efficiency of the purchase of materials for the construction of the house. The materials of the polyhedron are very useful in many other ways in human life, making the understanding and problem-solving ability in the materials of the solid figure very important to be mastered by the students. Internal factors such as prior knowledge, appreciation of mathematics and logical-mathematical intelligence affecting the ability to solve problems related to solid figures must be considered by the teacher.

Based on the explanation above, it is very important to take into account internal factors affecting the ability to solve mathematical problems. To scientifically figure out the contribution of the three factors, and given that there is no single research studying the contribution of the three factors toward the ability to solve mathematical problems, the researcher was interested to conduct research entitled "*Contribution of Prior Knowledge, Appreciation of Mathematics and Logical-Mathematical Intelligence toward the Ability to Solve Mathematical Problems in the Materials of Polyhedron in State Middle Schools Across Denpasar City".*

In this research, the errors made by students in solving mathematical problems in the materials of polyhedron will also be explored.

Research Methods

The population of this research was all students of grade IX of middle schools in Denpasar City, consisting of 3,583 students. The sampling technique used in this research was a stratified cluster random sampling technique with samples numbering 553.

The type of this research is an ex-post factor with the quantitative approach. In this research, to find the contribution of appreciation of mathematics (X_1), logical-mathematical intelligence (X_2), and prior knowledge (X_3) toward the ability to solve mathematical problems (Y), path analysis technique was employed.

In exploring the errors made by the students, the research subjects were taken based on the test of the ability to solve mathematical problems given. The research subjects were taken from students with a level of errors considered by the researcher as representing the errors of every student at every school with accreditations A and B.

Results and Analysis

The results of the path analysis can be seen in the following path diagram

The results of the hypothesis test in this research show that all path coefficients in every variable were significant at alpha 0.05. It can be concluded that exogenous variables have direct and indirect significant contribution toward endogenous variables. In Figure 1 above, it can also be seen that each path coefficient has a value greater than 0.05, thus all path coefficients obtained are significant. In the model testing, a coefficient of Q = 1 is also obtained. This shows that the causal relationship model of variables appreciation of mathematics (X_1), logical-mathematical intelligence (X_2), and prior knowledge (X_3) on the ability to solve mathematical problems (Y) obtained is perfectly fit and appropriate. The results of the calculation of direct contribution, indirect contribution and a total contribution of appreciation of mathematics (X_1), logical-mathematical intelligence (X_2) and prior knowledge (X_3) toward the ability to solve mathematical problems (Y) are summarized in Table 1.

Table 1
Direct contribution, indirect contribution and total contribution of the causal relationship of X_1, X_2, X_3 toward Y

Variable Contribution	Path Coefficients (Determination)	Contribution		Remainder	Total
		Direct	Indirect through X_3		
$x_1$toward x_3	0.523	52.3%	-	-	52.3%
$x_2$toward x_3	0.636	63.60%	-	-	63.60%
x_1, x_2 toward x_3	0.744	74.4%	-	25.60%	100.00%
x_1 toward Y	0.64	64%	14.6%	-	78.6%
x_2 toward Y	0.264	26.40%	17.81%	-	44.21%
x_3 toward Y	0.28	28%	-	-	28%
x_1, x_2, $x_3$toward Y	0.903	90.3%	-	9.70%	100.00%

In Table 1, it can be seen that the direct contribution of appreciation of mathematics to prior knowledge fits with the path coefficient as much as 52.3 percent through relationship form $X_3 = 0.523X_1 + 0.636X_2 + 0.506\varepsilon_3$. This means that the strength of X_1 directly determining the changes of X_3 is as much as 52.3% if X_2 is maintained to be constant. Appreciation of mathematics arising in the students' selves may improve the awareness, spirit, and passion to learn mathematical materials. Thus, the students will have sufficient prior knowledge to learn mathematical materials at higher levels. NCTM (2000), states that teachers implicitly provide structured information and experience that form the basis of students' confidence in mathematics. This confidence on mathematics gives huge influence to their willingness to be engaged in the tasks and activities of mathematical learning. The research conducted by Reed, Drijivers & Kirschner (2009), concludes that in developing mathematical learning, some factors must be improved, including the improvement of students' attitude, the improvement of the level of students behavior that is oriented to the objectives of the learning and the provision of adequate opportunity to construct new mathematical knowledge from the mastery of instruments.

The contribution of logical-mathematical intelligence toward the students' prior knowledge presented in Table 1 amounts 63.6 percent through the relationship form $X_3 = 0.523X_1 + 0.636X_2 + 0.506\varepsilon_3$. This means that 63.6 percent of the changes X_3 constituting the effect of X_2 if X_1 is maintained to be constant. This indicates that students who have good logical-mathematical intelligence are able to think systematically and logically, which will be effective in solving problems and in understanding abstract systems and mathematical calculation. According to Stern (2015), intelligence also affects a considerable number of concepts that can be mastered by students in their prior knowledge. Thus, in this case, logical-mathematical intelligence functions as a facilitator for the students in understanding the concepts of mathematical prior knowledge. As students have good logical-mathematical intelligence, they will be interested to learn mathematics and they will be able to master more concepts in the prior knowledge in the mathematics subject.

The results of this analysis also show that the simultaneous contribution of appreciation of mathematics and logical-mathematical intelligence toward prior knowledge amounts 74.4 percent through the relationship form $X_3 = 0.523X_1 + 0.636X_2 + 0.506\varepsilon_3$ and the remaining 25.6 percent is the contribution of other variables that are not considered. This means that appreciation of mathematics and logical-mathematical intelligence can explain the variety of prior knowledge as much as 74.4 percent. Intelligence will play a role in the selection of learning atmosphere and environment that is conducive and that influence many fields or concepts that can be mastered by students in their prior knowledge. The appreciation of mathematics arising in the students' selves also leads to the birth of curiosity, spirit, and resilience to learn the materials of triangles and rectangles in the mathematics subject optimally. A tendency is seen that if students are able to generate an appreciation of mathematics and have good logical-mathematical intelligence, the students will be able to master prior knowledge well.

The research having been conducted shows that the appreciation of mathematics directly contributes toward the ability to solve mathematical problems as much as 64 percent through the relationship form $Y = 0.64X_1 + 0.264X_2 + 0.28X_3 + 0.311\varepsilon_Y$ with a correlation coefficient of 0.83. This means that the strength of X_1 that directly determines the changes of Y amounts 64 percent if X_2 and X_3 are maintained to be constant. Appreciation of mathematics is the most important part in mathematics to improve the students' ability in mathematical learning, particularly in solving mathematical problems. This is supported by the Department of National Education (2006), stating that one of the objectives of mathematical learning is to enable students to appreciate the usefulness of mathematics in life, namely having curiosity, attention, and interest in learning mathematics, as well as the resilience and confidence in solving problems. The percentage of the indirect influence of mathematics on the ability to solve mathematical problems through prior knowledge is 14.6 percent. This means that 14.6 percent of the changes in the ability to solve mathematical problems constitutes the influence of appreciation of mathematics through prior knowledge. The appreciation of mathematics arising in the students' selves will give rise to the spirit in actively engaged in the learning process in the classroom. The more actively the students are engaged in the learning process, the more knowledge is to be mastered by the students. Thus, the students will be able to more optimally master the prior knowledge in understanding the formulae, operating the formulae as well as practicing systematic, logical and careful thinking. Good prior knowledge will reinforce the students' understanding of the main materials. As a result, the students will be able to solve the mathematical problems well.

The results of the research also show that logical-mathematical intelligence also directly and significantly contributes toward the ability to solve mathematical problems. A path coefficient of 0.264 is obtained through the relationship form $Y = 0.64X_1 + 0.264X_2 + 0.28X_3 + 0.311\varepsilon_Y$, which means that the logical-mathematical intelligence contributes as much as 26.4 percent toward the ability to solve mathematical problems. This means that the strength of X_2 directly determines the changes of Y as much as 26.4 percent if X_1 and X_3 are maintained to be constant. The characteristics of logical-mathematical intelligence such as analyzing, relating patterns, information and relationships as well as being careful in thinking are required in the steps of solving mathematical problems. Intelligence also plays a role in selecting and managing one in the environment or field he or she is engaged in. This is in line with the results of the research conducted by Stern (2015), that states that an individual who lives in a conducive environment to stimulate his or her cognition, prior knowledge and intelligence are closely related to each other. Intelligence will have a role in determining and influencing the number of fields or concepts to be mastered by students in their prior knowledge. Afterward, the concepts having been mastered by students will be used in solving mathematical problems in a material. This is supported by the results of research stating that logical-mathematical intelligence has an indirect influence on the ability to solve mathematical problems as much as 17.81 percent. This means that 17.81 percent of the changes in the ability to solve mathematical problems constitute logical-mathematical intelligence through prior knowledge. Thus, the overall contribution of logical-mathematical intelligence to the ability to solve mathematical problems is as much as 44.21 percent.

Prior knowledge has direct contribution toward the ability to solve mathematical problems as much as 28 percent through the relationship form $Y = 0.64X_1 + 0.264X_2 + 0.28X_3 + 0.311\varepsilon_Y$ and a correlation value of 0.837. It can be seen that the strength of X_3 directly determining the changes in Y amounts 28 percent if X_1 and X_2 are maintained to be constant. Students' prior knowledge contains the concepts of triangles and rectangles that serve as something that the students need to solve mathematical problems in the materials of the polyhedron, for instance, in the mathematical problem that is related to finding the surface area of roof-tiles of a building that has a pyramid-shaped roof. If the students do not have a good understanding of the concept of the area of triangles, they tend to forget the formula of the area of triangles.

The results of the analysis also show that appreciation of mathematics, logical-mathematical intelligence, and prior knowledge contribute simultaneously and significantly toward the ability to solve mathematical problems. The results of the analysis show a correlation coefficient of 0.95, which means that there is a very strong relationship between appreciation of mathematics, logical-mathematical intelligence, prior knowledge and the ability to solve mathematical problems. Meanwhile, the determination coefficient obtained is 0.903 through the relationship form $Y = 0.64X_1 + 0.264X_2 + 0.28X_3 + 0.311\varepsilon_Y$. This means that the simultaneous contribution of appreciation of mathematics, logical-mathematical intelligence, and prior knowledge is very high at 90.3 percent, while the remaining 9.7 percent is influenced by other factors that are not considered in the model. Another role of logical-mathematical intelligence is determining the number of mathematical concepts (Stern, 2015). In this research, the concepts referred to are the concepts of triangles and rectangles. These concepts of triangles and rectangles are stored in the students' prior knowledge. Then, the concepts of triangles and rectangles such as the area and circumference of triangles and rectangles are used in solving mathematical problems regarding polyhedron. Meanwhile, appreciation of mathematics is related to the productive disposition, which constitutes one of skillfulness in mathematical learning (Kilpatrick *et al.*, 2001). Students who have a good appreciation of mathematics will give appreciation and have a correct understanding of mathematics subject. This correct understanding will lead to passion in learning mathematics, thus the students will have the ability to solve mathematical problems.

After administering the written test, the researcher checked the answers of the students' problem-solving ability test right off. The results of the analysis of students' errors show that the students made errors in the interpretation of questions, errors in concepts, errors in writing and weaknesses in arithmetic skills. The following is the illustration of the students' errors.

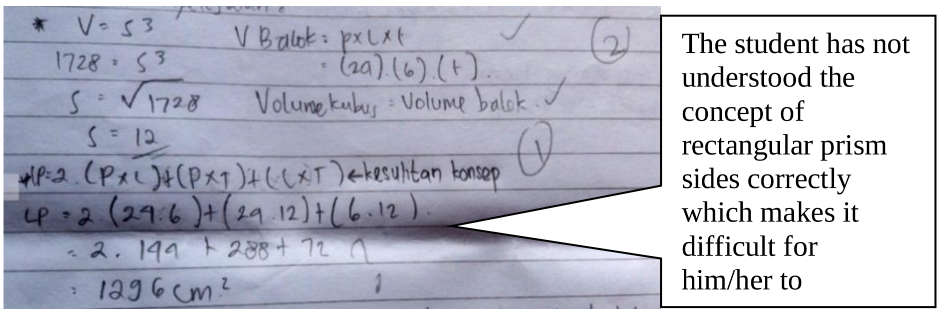

Figure 2. The Difficulty Faced by Student "W" in Terms of Concept when Solving Question 1

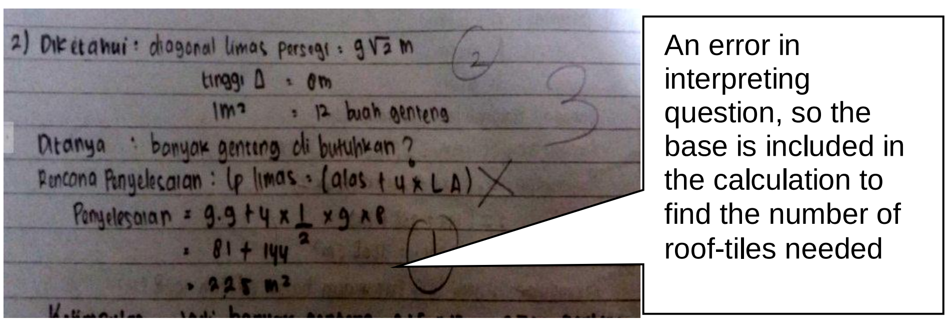

Figure 3 An Error in Interpreting the Question Made by Student "V" when Solving

The errors of concepts consisted of errors in the concept of surface area of rectangular prisms, errors in the concept of cube faces, errors in the concept of the height of pyramids, errors in the concept of the height of triangular prisms, and errors in the concept of the height in rectangular prisms in combined solid figures. In fact, these concepts had been learnt in the previous chapters. It can be seen that those errors in concepts caused the students to make wrong solutions or answers, which influenced their ability to solve mathematical problems. The findings in the analysis of students' answer sheets in the problem solving open-ended test also supported the results of the path analysis. From the path analysis, it was obtained that prior knowledge had a direct contribution toward the ability to solve mathematical problems as much as 28 percent with a correlation value of 0.837.

The other errors found were the weaknesses in arithmetic skills and errors in interpreting the questions. Question 4 is the question that shows the weaknesses in the students' arithmetical skills. The weaknesses lay in the operation of cube root, multiplication of decimal numbers and conversion of units. These skills have been taught since primary school. They are part of logical-mathematical intelligence. The findings in the analysis of students' errors also support the results obtained from the path analysis. From the path analysis, it was found that logical-mathematical intelligence had a direct and significant contribution toward the ability to solve mathematical problems as much as 0.264. This means that logical-mathematical intelligence contributes as much as 26.4 percent toward the ability to solve mathematical problems.

Then, the errors in interpreting question were due to the students' inability to imagine and understand the questions well. The students misinterpreted questions 2 and 3. In question 2 where the students were asked to find out the number of roof-tiles required, they could not interpret the sides of a pyramid that should have been included in the calculation. The students tried to find out the overall surface area and then find the number of roof-tiles needed, while actually, the base of the pyramid did not need any roof-tile. Therefore, the correct formula to be used in this case is the formula of the surface area of a pyramid without a base. The errors in interpreting questions made by the students were also found in question 3. It can be seen that the students tried to find the total area of a tent by finding the surface area of a pyramid without base added with the surface area of a rectangular prism without cover. In fact, the students were actually asked to find the total area of the tent without a base. Thus, they were required to find the surface area of a pyramid without base added with the surface area of a rectangular prism without both cover and base.

Conclusion

The results of the research show that: through the relationship form $X_3 = 0.523X_1 + 0.636X_2 + 0.506\varepsilon_3$, it was found out that (1) the contribution of appreciation of mathematics toward prior knowledge is as much as 52.3 percent, (2) the contribution of logical-mathematical intelligence toward prior knowledge is as much as 63.6 percent, and through the relationship for $Y = 0.640X_1 + 0.264X_2 + 0.28X_3 + 0.311\varepsilon_Y$ it was ound out that (1) the direct contribution of appreciation of mathematics toward the ability to solve mathematical problems is as much as 64 percent and the indirect contribution is as much as 14.6 percent. (2) the direct contribution of logical-mathematical intelligence toward the ability to solve mathematical problems is as much as 26.4 percent and the indirect contribution is as much as 17.81 percent, (3) the direct contribution of prior knowledge toward the ability to solve mathematical problems is as much as 28 percent, (4) appreciation of mathematics and logical-mathematical intelligence simultaneously contribute toward prior knowledge as much as 74.4 percent, (5) appreciation of mathematics, logical-mathematical intelligence, and prior knowledge simultaneously contribute toward the ability to solve mathematical problems as much as 90.3 percent.

The results of analysis of the students' errors reveal that the students still make errors in concepts, errors in interpreting questions, errors in writing and weaknesses in arithmetic skills. The errors in concepts made by students are related to the students' prior knowledge, while the weakness in arithmetical skills and errors in interpreting questions made by the students are related to logical-mathematical intelligence. All of the errors made by the students may influence the ability to solve mathematical problems.

Acknowledgements
The author would like to thank the editor for their valuable time and advice.

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