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ANALYSIS OF STUDENTS' ERRORS IN SOLVING HIGHER-ORDER THINKING SKILLS MATHEMATICAL PROBLEMS OF GEOMETRY BASED ON HADAR CRITERIA VIEWED FROM PRIOR KNOWLEDGE

Erwinda Gracya Laman[1)], Fitriani Halik[2)]
[1]Universitas Kristen Indonesia Paulus
[2]Politeknik Negeri Media Kreatif
[1]Jl. Perintis Kemerdekaan Km 13, Daya, Makassar, Indonesia
[2]Jl. Srengseng Sawah, Kec. Jagakarsa, Jakarta Selatan, Indonesia
E-mail: erwinda01@gmail.com[1)], fitriani960219@gmail.com[2)]

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Abstract:
This study aims to know the description of students' errors in solving Higher Order Thinking Skills (HOTS) mathematical problems and the description of errors differences in geometry based on Hadar criteria. This type of research is descriptive research using a qualitative approach. Retrieval of the subject is performed by providing a prior knowledge test of grade XII MIPA 3, then from the result of the test selected 6 subjects based on existing categories. The instrument used in this research is a prior knowledge test which contains 30 multiple choices, written tests of Higher Order Thinking Skills that contain 2 number of essay and interview guidelines. Errors are analyzed by using the Hadar error category which consists of 6 errors. The results of this research show that based on the Hadar error criteria, errors that occur are misused data, misinterpreted language, logically invalid inference, distorted theorem or definition, unverified solutions, and technical errors. Subjects who were solving HOTS mathematics problems of geometry tend to make logically invalid inferences, distorted definitions or theorems, and technical errors. The results of this research are expected to add insight into the types of errors made by the students of senior high school in geometry topics, especially in solving higher-order thinking skills problems so that the mistakes can be immediately minimized in the process of learning.

Keywords: Errors, Higher Order Thinking Skills, Hadar Criteria

ANALISIS KESALAHAN SISWA DALAM MEMECAHKAN MASALAH MATEMATIKA GEOMETRI HIGHER ORDER THINKING SKILLS (HOTS) BERDASARKAN KRITERIA HADAR DITINJAU DARI KEMAMPUAN AWAL SISWA

Abstrak:
Penelitian ini bertujuan untuk mengetahui deskripsi kesalahan siswa dalam memecahkan masalah matematika Higher Order Thinking Skills serta gambaran perbedaan kesalahan pada bidang geometri berdasarkan kriteria Hadar. Jenis penelitian ini adalah penelitian deskriptif menggunakan pendekatan kualitatif. Pengambilan subjek dilakukan dengan memberikan tes kemampuan awal kepada

siswa kelas XII MIPA 3 yang kemudian dari hasil tersebut dipilih 6 subjek penelitian berdasarkan kategori yang ada. Instrumen yang digunakan adalah tes kemampuan awal yang memuat dari 30 butir soal, tes tertulis Higher Order Thinking Skills yang memuat 2 butir soal uraian dan pedoman wawancara. Kesalahan dianalisis menggunakan kategori kesalahan Hadar yang terdiri dari 6 kesalahan. Hasil penelitian menunjukkan bahwa, kesalahan yang terjadi adalah kesalahan menggunakan data, kesalahan menggunakan bahasa, kesalahan menggunakan logika untuk menarik kesimpulan, kesalahan menggunakan definisi atau teorema, penyelesaian tidak diperiksa kembali, dan kesalahan teknis. Subjek yang mengerjakan soal HOTS materi geometri cenderung melakukan kesalahan menggunakan logika dalam menarik kesimpulan, kesalahan menggunakan definisi atau teorema, dan kesalahan teknis. Hasil dari penelitian ini diharapkan dapat menambah wawasan tentang jenis kesalahan yang dilakukan siswa SMA pada materi geometri khususnya dalam mengerjakan soal level tingkat tinggi sehingga dalam proses pembelajaran kesalahan-kesalahan yang dilakukan dapat diminimalisasi.

Kata Kunci: Kesalahan, Higher Order Thinking Skills, Kriteria Hadar

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INTRODUCTION

One of the basic competencies that students must have is problem-solving. Problem-solving is a very important part of the mathematics curriculum (Hartono, 2014). This is because students will gain experience in using their knowledge and skills to solve problems. Krulik & Rudnick (1999) state that problem-solving is an individual process of using the knowledge, skills, and understanding obtained to solve problems in unfamiliar situations. Polya (2004) states that there are four steps in solving a problem including understanding the problem, devising a plan, carrying out the plan, and looking back. Seeing the description of the explanation of problem-solving above, it is only natural that problem-solving ability is said to be one of the most important abilities to be mastered by students, especially in mathematics.

One of the mathematics skills is solving mathematics problems. Lubis, Panjaitan, Surya, and Syahputra (2017) state that problem-solving is the foundation of mathematics and the process of discovering new knowledge.

Genarsih, Kusmayadi, and Mardiyana (2015) state that solving mathematical problems is a way of finding answers to mathematical problems so that students can solve the mathematics problem. Bell (1978) explained that solving mathematical problems can help students develop their abilities and can help them apply their abilities to various situations. Helping students to have good skills in solving mathematics problems, needs several abilities, one of them is Higher Order Thinking Skills.

Higher Order Thinking Skills (HOTS) is a student thinking activity that involves high-level cognitive from Bloom's Taxonomy which includes analyzing, evaluating, and creating (Anderson & Krathwohl, 2015). HOTS is a skill in creating a relationship between what is learned and what will be learned, so this skill needs to be mastered (Singh, Singh, Mostafa, & Singh, 2017). HOTS is a skill that is more than remembering, understanding, and applying (Rosnawati, 2005), so HOTS questions are instruments or measurement tools used to measure higher-order thinking skills, namely the ability to think that does not just remember, restate, or refer to without processing, but the ability to think to analyze information critically, creatively, and be able to solve problems.

In solving HOTS Mathematics problems, students often experience difficulties in solving problems that cause errors. Abdullah, Abidin, and Ali (2015) state that students' errors when solving HOTS problems are not understanding the questions properly and lacking plans in the transformation process. According to Mullis, Martin, and Ruddock (2011) without good basic knowledge of mathematics, students will have difficulty remembering basic mathematical facts that are useful for mathematical thinking processes. However, having good basic knowledge does not necessarily mean that students do not make errors in solving HOTS questions. In solving HOTS problems students with good mathematical abilities usually do not make data errors or conclusions errors, but errors happen in the development of solving ideas. If it is related to the type of errors, then students who have good mathematical abilities do not need to make errors when solving HOTS problems, while students who do not have good abilities usually make errors in solving HOTS problems, errors are made not only in solving ideas but also making data errors, conclusion errors or other errors.

Movshovitz-Hadar, Zaslavsky, and Inbar (1987) give several types of errors in solving mathematics problems, which consist of misused data, misinterpreted language, logically invalid inference, distorted theorem or

definition, unverified solutions, and technical errors. Errors criteria according to Hadar are suitable ways to analyze the errors made by students when solving HOTS mathematical problems. This is in line with the results of previous research that subjects who completed HOTS problems on geometry material mostly had errors in using logic when making conclusions, definitions or formulae errors, and technical errors (Syahri, 2021). This is following the problems discussed by the researcher. In addition, this criteria of Hadar errors is also an international writing that is very worthy of being used as a reference.

Previous research was conducted by Syahri (2021) about the analysis of student errors in solving HOTS problems on number pattern material based on Hadar criteria which concluded that the errors made by students in solving HOTS mathematical problems on number pattern material based on Hadar criteria included misused data, misinterpreted language, logically invalid inference, distorted theorem or definition, and unverified solution. The research also conducted by Gais and Afriansyah (2017) about the analysis of students' abilities in solving HOTS questions concluded that the factors that caused students' errors in solving HOTS questions included the lack of thoroughness in the process of working on the questions, the student's prior mathematical abilities were low, the processes involved during learning were not optimal, the student's lack of understanding about the questions, and incompleteness in reading questions. Besides that, research was conducted by Komarudin (2016) about the analysis of student errors in solving mathematical problems and getting research results about there are 4 types of errors in solving problems of probability, namely errors in understanding the questions, errors in planning, errors in carrying out plans and errors in checking the solutions. This study distinguishes it from previous research in the material where no one researcher has researched the analysis of student errors in solving HOTS mathematical problems of geometry based on Hadar criteria.

In this study, the student errors in solving the problems are the types of errors given by Movshovitz-Hadar, Zaslavsky, and Inbar (1987) consisting of six errors: (1) misused data, (2) misinterpreted language, (3) logically invalid inference, (4) distorted definition or theorem, (5) unverified solution, (6) technical error.

In learning mathematics, some factors influence the learning process, namely the prior ability factor. Students' prior knowledge factors are different from one another. Mulyono (2017) states that prior knowledge is the

knowledge and skills that students have before continuing to the next level. Soekamto and Winataputra (1997) states that students' prior knowledge is the ability that students already have before participating in the learning that will be given by the teacher. The student's initial ability factor is considered the most influential, as stated by Karso, Suyadi, Muhsetyo, Chadra, Widagdo, and Priatna (2008) the prior knowledge factor of students is an important factor in the process of teaching and learning mathematics. These factors depend on students such as intelligence, readiness, and skills of students.

To find out the errors and causes of student errors in solving problems can be done by analyzing errors through student responses in answering a question. One of the ways to describe and analyze the errors made by students in solving Higher Order Thinking Skills (HOTS) problems is to analyze student answers using the Hadar criteria based on students' prior knowledge. Through error analysis based on Hadar criteria, it will be possible to obtain types of student errors in solving HOTS mathematical problems, so that student errors can be minimized and used by teachers for teaching considerations to improve learning and teaching activities of mathematics material with the correct concept. By knowing the errors experienced by students, it is hoped that the teacher can take appropriate corrective steps for the next teaching and learning process and later it is hoped that this will increase mathematics achievement. Based on that, a researcher is interested in researching student errors in solving HOTS mathematical problems. This study aims to determine the description of students' errors in solving HOTS mathematical problems based on Hadar criteria.

METHODS

This study uses a qualitative approach. The subjects of this research were 3 students in grade XII. Retrieval of the subject of this study was based on the results of the prior knowledge test given, then the test results were sorted starting from the highest, moderate, to the lowest test results. From the prior knowledge score, the researcher then determines students into the category of test results. There are three categories of prior knowledge according to Maryam (2016), the following categories are:

1. Category of students with high prior knowledge ($80 \leq x \leq 100$)
2. Category of students with moderate prior knowledge ($60 \leq x < 80$), dan
3. Category of students with low prior knowledge ($x < 60$).

Students who have been grouped, are then taken one to represent each category and then given HOTS questions on geometry material. After that, the students were interviewed regarding the answers they had written and analyzed the errors they made.

Data collection techniques in this study include: (1) Prior knowledge mathematical test, (2) HOTS problems test, and (3) interviews The prior knowledge mathematical test was given to find out students' initial understanding of geometry material to take research subjects who will be given HOTS mathematical questions. This test consists of 30 multiple multiple-choices. While the HOTS test questions referred to in this study are written tests in the form of essay tests about geometry. This test aims to reveal students' errors in solving HOTS mathematical problems in geometry material. After solving the questions on the test, interviews were conducted as triangulating answers written by research subjects to know and find out the subject's errors in solving the given questions.

The instrument used has been validated by 2 validators. The validity of the data was carried out by technical triangulation by comparing the data obtained from the HOTS test questions and the data obtained from interviews.

Data analysis in this study includes: (1) Analysis of data mathematical prior knowledge, (2) Analysis of HOTS test results on geometry material, and (3) Interview analysis consisting of three steps (Miles, Huberman, & Saldana, 2014) includes data condensation, data presentation, and conclusions drawing.

RESULTS AND DISCUSSION

1. Subject's Error with High Mathematics Prior Knowledge

Table 1. Determination of research subjects

No.	Students Initials	Prior Knowledge	Test Score	Students Code
1.	AT	High	83	S1
2.	AHS	Moderate	63	S2
3.	MMAN	Low	16	S3

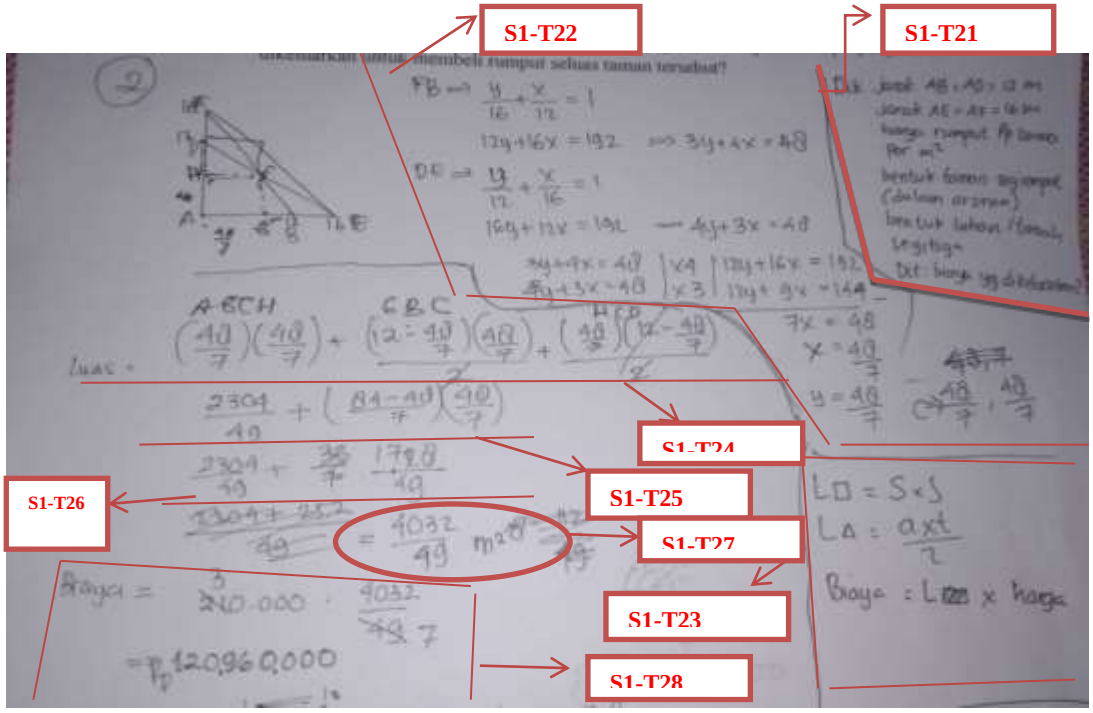

Figure 1. HOTS written test result of the subject with High Mathematics Prior Knowledge (AT)

In figure 1, it can be seen that the subject has written down the given information and asked for information (S1-T21). The subject has also completed the problem using systematic steps. But in the last, step the subject made a miscalculation in determining the cost so that the subject got the cost about *Rp* 120.960.00,00 (S1-T28) which should *Rp* 17.280.000,00. After being confirmed through interviews, it turned out that the subject was not aware of the error he had made (Transcript 1).

Transcript 1

P	:	*After the area of the triangle is obtained, what is the next step??*
S2-W211	:	*The question asked is the cost, so that the cost of grass per meter is multiplied by the area and the result is Rp.120.960.000*
P	:	*Do you think the answer is correct? Is the calculation method correct?*
S2-W212	:	*I think that's correct!*

Transcript 1 shows that it is true that the subject was not aware of the calculation error he made and believed that the answer was correct (S2-W211). So it can be said that the subject made a technical error in solving HOTS problems of geometry.

2. Subject's Error with Moderate Mathematics Prior Knowledge

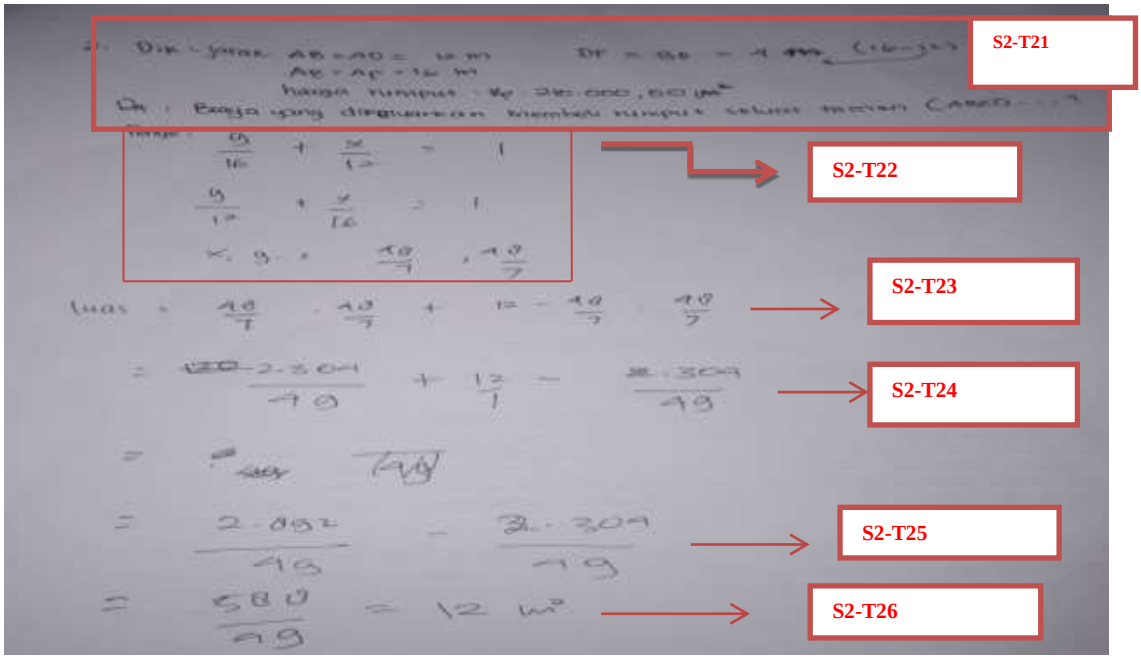

Figure 2. HOTS written test result of the subject with Moderate Mathematics Prior Knowledge (AHS)

In figure 2, it can be seen that the subject has written down the given information and asked information about the question (S2-T21). The subject also got the line equation of the given information from the problem, but the subject did not write down the process of getting the values x and y (S2-T22). Then, the subject determines the area of a quadrilateral by adding up the area of the square and the area of one triangle. So, the sum of the areas of a square and a triangle is the area of the quadrilateral of the shaded figure of the problem (S2-T26). However, after being confirmed through interviews, it turned out that the subject was not aware of the errors (Transcript 2).

Transcript 2

P : *Where did you get the idea to make equations like these:* $\frac{y}{16}+\frac{x}{12}=1$ *and* $\frac{y}{12}+\frac{x}{16}=1$*?*

S2-W215 : *These were the line equation based on the information from the question, I used the line equation to determine the equation. After I get two equations then these were eliminated to get* x *and* y*. The value of* x *and* y *which will later be used to find the length of other lines in the figure of the question. However, I did not write down the steps because I was in a hurry.*

P	:	*Where did you find The area* $= \frac{48}{7}x\frac{48}{7} + 12 - \frac{48}{7}.\frac{48}{7}$*?*
S2-W219	:	$\frac{48}{7}x\frac{48}{7}$ *was the area of the square then* $12 - \frac{48}{7}.\frac{48}{7}$ *were the area triangle because to find the shaded area I could add the area of the square and the area of a triangle and I got* $12\ m^2$*.*

Transcript 2 shows that it is true that the subject did not write down the process of determining the value of x and . The subject then determines the area of the shaded region by adding up the area of the square and the area of a triangle. The subject made a mistake in drawing conclusions where the subject divided the two areas into a square and a triangle to get the total area and did not realize the errors (S2-W219). So it can be said that the subject made an error logically invalid inference in solving HOTS problems of geometry.

In figure 2, it can be seen that the subject did not write down the formula to find the area of the square and the area of a triangle in solving the problem. In applying the formula to find the area of the triangle the subject only applied it in the form of $a\ x\ t$ (S2-T23). After being confirmed through interviews the subject realized his error in applying the formula of the area of a triangle and forgot to write down the formula of the area of the square and the area of a triangle (Transcript 3).

Transcript 3

P	:	*Why didn't you write down the formula?*
S2-W221	:	*I forgot and I was running out of time*
P	:	*The area of the triangle =* $\frac{a\ x\ t}{2}$ *but why in your answer just wrote down* $a\ x\ t$*?*
S2-W222	:	*I just realized that I should have written* $\frac{a\ x\ t}{2}$ *not only* $a\ x\ t$*.*

Transcript 3 shows that it is true that the subject forgot to write down the formula to find the area of the square and the area of a triangle (S2-W221), and the subject realized that the application of the formula of the area of a triangle $a\ x\ t$ that he written was wrong and it should be $\frac{a\ x\ t}{2}$(S2-W22). So that it can be said that the subject made did distorted theorem or definition in solving HOTS problems of geometry.

Transcript 4 shows that it was true that the subject did not look back at the answers (S2-W234). So that it can be said that the subject made an error, which was an unverified solution in solving HOTS problems of geometry.

Transcript 4

P	:	*Did you look back at your answer?*
S2-W234	:	*I didn't have time to look back at the answer because time was up*

In figure 2, it can be seen that in determining the area of a triangle with the formula $\frac{a\ x\ t}{2}$, subject wrote down $12 - \frac{48}{7} . \frac{48}{7}$, it should be $\frac{\left(12-\frac{48}{7}\right).\frac{48}{7}}{2}$ (S2T23). But, after being confirmed through interviews, it turned out that the subject realized the error he made in solving the questions (Transcript 5)

Transcript 5

P	:	*Look at the way to find the area of a triangle. Why was* $\frac{48}{7} . \frac{48}{7}$ *operated first?*
S2-W225	:	*Because if there are subtraction and multiplication, I did the multiplication first*
P	:	*Are you sure?*
S2-W226	:	*Oh My God, I'm sorry there should be parentheses of* $12 - \frac{48}{7}$ *because the base has just been multiplied by* $\frac{48}{7}$.

Transcript 5 shows that it is true that the subject made a calculation error in determining the area of a triangle (S2-W226). So it can be said that the subject made a technical error in solving HOTS problems of geometry.

3. Subject's Error with Moderate Mathematics Prior Knowledge

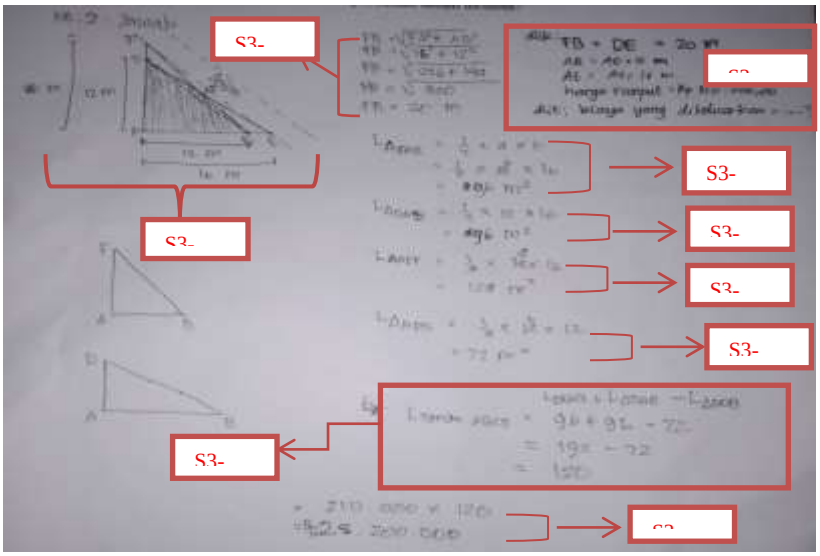

Figure 3. HOTS written test result of the subject with Low Mathematics Prior Knowledge (MMAN)

In figure 3, it can be seen that the subject has written down the given information and asked information in the questions (S3-T21) but the subject was not able to change the given information from the question into the mathematical model so the subject was wrong in determining how to get the area of a quadrilateral where to add up the area of ΔFAB, ΔDAE then subtract with the area of ΔADB (S3-T28). After being confirmed through interviews, it turned out that the subject was not realized the error in determining the area of the quadrilateral (Transcript 6).

Transcript 6

P	:	*After getting the information from the question, what was the next step?*
S3-W25	:	*I started counting it. Firstly, I count the distance between angle* F *to* E, *I got* $20\ m$. *Secondly, I determined the area of the triangle Cap* FAB *became* $96\ m^2$ *and it was the same as the area of triangle* DAE *where triangle* FAB *intersects the ark. Then, I determined the area of triangle* AEF *and got* $128\ m^2$. *Then I subtract the sum of the area of triangle* FAB *and the area of triangle* DAE *with the area of triangle* AEF *and I got* $120\ m^2$, *it was the area of the park. Last, I multiplied the cost of grass and I got* $Rp\ 25.200.000{,}00$.
P	:	*Did you think your answer is correct?*
J	:	*I think so*

Transcript 6 shows that it is true that the subject did not realize the error in determining the area of the quadrilateral and was not able to understand the question sentences well so the subject made an error in changing the information into a mathematical model which resulted in the subject making error in determining the area of the quadrilateral and the cost to buy the grass was $Rp\ 25.200.000{,}00$ (S3-W25) which should be $Rp\ 17.280.00{,}00$. It could be said that subject did misinterpret language in solving HOTS problem of geometry.

In figure 3, it can be seen that the subject was initially looking for the length of FB by using the formula of Pythagorean theorem (S3-T23), then finding the aarea of the triangle in the figure, these are ΔFAB (S3-T 24), ΔDAE (S3-T25), ΔAEF (S3-T26) and ΔDAB (S3-T27). Then determine the area of the quadrilateral obtained from the total area of ΔFAB and ΔCapthen substracted with the area of ΔDAB (S3-T28) which should be the shaded area of he total area of square and the area of two triangles. Because the subject did an error determining the area of the quadrilateral, the subject also found the wrong counting to buy grass. The subject got $Rp\ 25.200.00{,}00$ which should be

Rp 17.280.00,00. After being confirmed through interviews the subject did not realize the errors (Transcript 7).

Transcript 7

P	:	*After collecting the given information from the question, what was the next step?*
S6-W25	:	*I tried to count it. Firstly I count the distance between angles* F *to* E *and I got* $20\ m$*. Secondly, I determine the area of triangle* FAB *and I got* $96\ m^2$ *and it was the area of triangle* DAE *which the triangle* FAB *intersectshe park. Then I determine the area of triangle* AEF *and the result was* $128\ m^2$*. Then I subtracted the total area of triangle* FAB *and the area of triangle* DAE *with the area of triangle* AEF *and I got* $120\ m^2$*, that was the area of the rk The last, I multiplied it by the cost of grass and I got* Rp 25.200.000,00*.*

Transcript 7 shows that the subject correctly determines the area of the shaded figure by adding up the areas of ΔFAB dan ΔDAE then ssubtracting the area of ΔDAB and found the cost of grass was Rp 25.200.000,00 which should be Rp 17.280.00,00. So it can be said that the subject did logically invalid inference in solving HOTS problems of geometry.

Table 2. Differences of Subject Errors in Solving Geometry HOTS Problems

Types of Errors	**Subject**		
	S1	S2	S3
Misused Data	-	-	-
Misinterpreted language	-	-	√
Logically invalid inference	-	√	√
Distorted theorem or definition	-	√	-
Unverified solution	-	√	-
Technical Error	√	√	-

In table 2, it shows the difference in the number of errors made by each subject. S1 with high prior knowledge made one error, which was a technical error where the subject made an error calculation. Compared to other subjects, S2 with moderate prior knowledge made the most errors compared to S3 with low prior knowledge. Students with high prior knowledge can be said to be superior in solving the given questions because the subject has a good level of analysis. This statement is supported by Payung, Ramadhan, and Budiarsa (2016) stated that if the student's prior knowledge is high, in the next learning

process the student will more easily understand the concept of the material and will not find difficulties.

In addition, it can be seen that students with high-level prior knowledge can also plan well, can use all given information to solve problems, and can find the solutions according to the plans made. The subject is also able to write down how to look back at the answers that have been obtained. This is supported by the results of a dissertation made by Hailikari (2010) stated that students who have good prior knowledge will easily solve the problems.

Meanwhile, subjects with moderate prior knowledge were making error logically invalid inferences. In this type of error, the subject draws wrong conclusions in determining the first steps in solving the problem. This is in line with the research by Wahyuningsih (2020) stated that errors of logically invalid inference are where students draw conclusions that are not quite right to solve problems. The subject also made errors using definitions or theorems. In this error, the subject applies the formula in inappropriate conditions. This is in line with research Wahyuningsih (2020) stated that Errors in using definitions or theorems were where the subject made errors in applying formulas to solve the problems. In addition, the subject also made an error unverified solution. In this type of error, the subject was wrong in writing the final answer. This is in line with the research by Wahyuningsih (2020) stated that unverified solutions occurred because the solution was not checked again when the subject was wrong in writing the final answer. The subject also made a technical error. In this type of error, the subject was wrong in making calculations. This is in line with the research Movshovitz-Hadar Zaslavsky, and Inbar (1987) stated that Technical errors that may occur are calculation errors, errors in citing data, and errors in manipulating algebraic symbols.

Subjects with low prior knowledge made errors in interpreting language. In this type of error, the subject does not understand the meaning of the problem, so the subject changes the problem into a mathematical model with a different meaning. This is in line with research by Putri (2018) stated that an Error in interpreting language is when the subject misunderstood the question sentence and the subject was not able to change the given information from the problem into the correct mathematical model. In addition, the subject did an error of logically invalid inference. In this type of error, the subject draws wrong conclusions in determining the first step in solving the problem. This is in line with research Wahyuningsih (2020) stated that logically invalid inference is where students draw inaccurate conclusions to solve problems.

CONCLUSIONS

Subjects with high prior knowledge in solving HOTS mathematical problems of geometry only made one error, which is a technical error. Subjects with moderate prior knowledge in solving HOTS mathematical problems of geometry made four types of errors, these are: (1) logically invalid inference, (2) distorted theorem or definition, (3) unverified solution, (4) technical error. Subjects with low prior knowledge in solving HOTS mathematical problems of geometry made two types of errors, these are: (1) misinterpreted language, (2) logically invalid inference. The results of written tests and student interviews prove that errors are not only made by students with low prior knowledge or high error subject groups, but students with moderate prior knowledge still make errors in solving problems.

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