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# STUDENTS' ERROR IN SOLVING HOTS-CATEGORY MATHEMATICS PROBLEMS VIEWED FROM DIDACTIC TRIANGLE

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## Abstrak

Kesalahan siswa dalam menyelesaikan soal matematika kategori *Higher-Order Thinking Skills* (HOTS) dapat disebabkan oleh proses pembelajaran yang dialami oleh siswa. Dalam proses pembelajaran terdapat tiga komponen yang saling berkaitan, yaitu siswa, guru dan materi yang dapat digambarkan dalam segitiga didaktis, yaitu Hubungan Didaktis, Hubungan Pedagogis dan Hubungan Antisipasi Didaktis-Pedagogis. Penelitian ini bertujuan untuk mendeskripsikan kesalahan siswa dalam menyelesaikan soal matematika kategori HOTS dan penyebabnya ditinjau dari segitiga didaktis. Penelitian ini menggunakan metode studi kasus dengan pendekatan kualitatif yang dilakukan pada salah satu SMA Negeri di Provinsi Bengkulu, dengan melibatkan tiga orang siswa kelas X sebagai subjek penelitian. Pengambilan data dilakukan secara triangulasi dengan menggunakan teknik tes, wawancara, dan studi dokumen. Hasil dari penelitian ini menunjukkan bahwa kesalahan muncul pada penyelesaian setiap soal matematika kategori HOTS yang meliputi kesalahan dalam menggunakan konsep, perhitungan, dan tidak menyelesaikan soal. Ditinjau dari segitiga didaktis, kesalahan tersebut terjadi pada siswa yang tidak belajar melalui sumber yang diberikan, aktivitas pembelajaran yang cenderung monoton, respon siswa yang pasif selama pembelajaran, dan guru hanya berfokus pada pembelajaran secara konvensional. Dengan demikian, pembelajaran yang dialami siswa belum dapat mendorong siswa untuk berpikir pada level HOTS.

**Kata kunci**: Kesalahan Siswa; Segitiga Didaktis; Soal Matematika Kategori HOTS.

## *Abstract*

*Student errors in solving Higher-Order Thinking Skills (HOTS) category math problems can be caused by the learning process experienced by them. In the learning process, there are three interrelated components, namely students, teachers, and materials which can be described in a didactic triangle, namely Didactic Relationship, Pedagogical Relationship, and Didactic-Pedagogical Anticipation Relationship. This study aims to describe students' error in solving HOTS-category math problems and the causes of these errors viewed from the didactical triangle. This study used a case study method with a qualitative approach conducted at one of the senior high schools in Bengkulu Province, involving three $10^{th}$-grade students as research subjects. Data were collected by using test, interview, and document study techniques. The results of this research show that errors appeared in the completion of each HOTS-category math problem, consisting of errors in using concepts, calculations, and failing to solve the problem. Viewed from the didactic triangle, these errors occur when students do not learn through the resources provided, learning activities tend to be monotonous, passive-student responses during the learning process, and teacher only focuses on conventional learning. Thus, the learning process experienced by students is unable to encourage them to think at the HOTS level.*

***Keywords**: Didactic triangle; HOTS-category math problems; students' error*

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## INTRODUCTION

The ability to think at a high level is one of the thinking skills that every individual needs to have. In line with the opinion of Kemendikbud (2019) who states that one of the most important competencies in the modern world is abilities to think at a high level so these abilities must be possessed by students. Higher-Order Thinking Skills (HOTS) cannot be obtained instantly but must be trained as thinking skills through learning activities that support their development (Retnawati et al., 2018) Thus, this ability can be trained through a learning process, especially through mathematics.

One way to train HOTS through mathematics is by applying HOTS problems in learning. According to Anderson and Krathwohl (2001), HOTS problems generally measure thinking skills at the level of analyze (C4), evaluate (C5), and create (C6). HOTS questions are assessments related to real-world problems in daily life and students are expected to apply the concept they have learned in the classroom to be able to solve problems (Widana, 2017). Therefore, HOTS-category math problems are questions related to problem-solving situations or events in daily life.

HOTS-category math problems are not only a challenge for students, but teachers also feel the same way. The concept of HOTS itself is a complex concept so many teachers have difficulty in understanding HOTS. Several studies show that teachers' understanding of HOTS and their ability to improve students' HOTS is still lacking, which causes the implementation of HOTS-based problems in the classroom is not optimal (Acharya, 2021; Retnawati et al., 2018). This lack of implementation has an impact on the evaluation that will be applied by the teacher. Teachers tend to provide evaluations based on what they teach. The lack of HOTS application in a classroom causes the rare application of HOTS-based evaluations so when students are faced with it, students will have difficulties in solving the problems given. This difficulty experienced by students cause them to make errors.

Several studies relevant to error analysis have been conducted using different error analysis indicators (Cahyani & Sutriyono, 2018; Hidayati, 2020; Mensah, 2017; Rachman & Saripudin, 2020; Savitri & Yuliani, 2020; Wardhani & Argaswari, 2022; Widodo & Sujadi, 2015). In particular, studies that discuss students' error and difficulties in solving HOTS problem also have been conducted (Febryana et al., 2023; Karimah et al., 2018; Khusna et al., 2021; Pramesti & Retnawati, 2019; Sulistyowati et al., 2019; Yulianti & Novtiar, 2021). The result of these studies described students' errors and their causes such as carelessness in doing calculation, weakness in basic arithmetical operation, lack of mastery concept, and so on.

The studies that mentioned above are focus on students in describing the causes of errors. In fact, the causes of these errors do not only come from students but also come from the learning process that students experienced. In the learning process, there are three interrelated components, namely students, teachers, and materials. The relationship of these components is contained in the didactic triangle that has been modified by Suryadi (2010), namely the Didactic Relationship (student-material), Pedagogical Relationship (student-teacher), and Didactic-Pedagogical

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Anticipation Relationship (teacher-material). Didactic relationship according to Kansanen (2003) is the relationship between students and content or material. This relationship can be interpreted as the relationship between student learning and the learning process. A pedagogical relationship is defined as the relationship between students and teachers that involves interaction between them (Kansanen & Meri, 1999). The didactic-pedagogical anticipation relationship is interpreted as the teacher's prediction and anticipation of students' responses to the didactic situation that has been designed to create a new didactic situation (Suryadi, 2010). Therefore, the didactic triangle focuses on the learning process.

In the didactic triangle, the most important role of educators is to create a didactic situation and pedagogical situation to improve the quality of learning (Suryadi, 2010). Didactic situations are circumstances that can trigger mental action in didactic relationships (Prabowo & Juandi, 2020) while pedagogical situations are situations related to the relationship between teachers and students (Suryadi, 2010). In reality, both situations can occur simultaneously (Suryadi, 2010). Thus, didactical and pedagogical situations that occur in the learning process cannot be viewed separately.

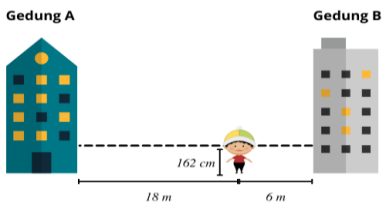
According to the results of previous studies, no references have been found that reveal the causes of students' errors viewed from the learning process experienced by them. Based on the explanation above, it is necessary to study students' errors viewed from the learning process. In this case, the didactic triangle is used as a reference to see the students' learning process. Therefore, this study aims to explore students' errors and the causes of these errors viewed from the modified didactic triangle.

## RESEARCH METHOD

This study used a case study method with a qualitative approach conducted in one of the senior high schools in Bengkulu City, Bengkulu Province, involving three $10^{th}$-grade students as research subjects. The selection of subjects was based on errors that appeared in students' answers when solving HOTS problems and discussion with the mathematics teacher who taught the subjects.

Data were collected using triangulations, namely document analysis, test instruments, and interviews. The test instrument in the study was in the form of HOTS questions on trigonometry material presented in the Table 1.

Table 1. HOTS problems test instrument on trigonometry material

| No. | Problem | Cognitive Level |
|---|---|---|
| 1 | Take a look at the following figure!   | C5 (Evaluate) |

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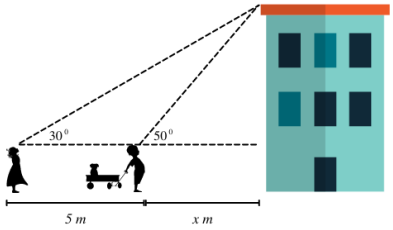
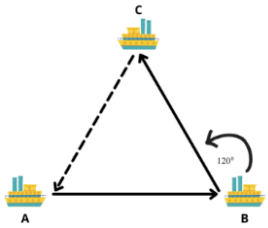
| No. | Problem | Cognitive Level |
|---|---|---|
| | A child is standing between two buildings, building A and building B. The child sees the top of building A with an elevation angle of 30° and the top of building B with an elevation angle of 60°. If the distance between the child and building A is 18 meters and the distance between the child and building B is 6 meters and the child's height is 162 centimeters (measured to the eye), verify whether the two buildings have the same height or not. Explain your answer! | |
| 2 | A boy and a girl are standing around the building as shown below.   The girl is looking at the top of the building at an angle of 30°, while the boy is looking at the top of the same building at an angle of 50°. The distance between the boy and the girl is 5 meters and between the boy and the building is $x$ meters. If both children have the same height of 160 centimeters (measured to the eye), construct a mathematical model to determine the height of the building! | C6 (Create) |
| 3 | Take a look at the following figure!   A ship sails at 7:00 a.m. from port A eastward to port B and arrives at 9:00 a.m. after traveling 60 kilometers. At noon (12:00 p.m.), the ship continues its voyage to port C by turning course by 120° and arriving at 3:00 p.m. after traveling 90 kilometers. If the ship continues its journey at 4:00 p.m. to port A and arrives at 8:00 p.m., determine the speed traveled by the ship when heading to port A! | C4 (Analyze) |
| 4 | Luffy and Zoro are standing on the shoreline 8 km apart and see a fishing boat floating in the sea. Suppose Zoro, Luffy, and Boat form an angle of 15°. Meanwhile, Luffy, Zoro, and Boat form an angle of 30°. If the distance between Luffy and the boat is $p\sqrt{q}$ kilometers, where $p\sqrt{q}$ is the simplest form, determine the value of $p \times q$. | C4 (Analyze) |

The problems presented in Table 1 were given to 28 students and 3 out of 28 students were selected as research subjects for further analysis through interviews. The interview used in this study was a semi-structured interview which aims to explore the causes of students making errors in solving HOTS problems because this kind of interview is categorized as in-depth interview. The interview were conducted with research subjects and teaching teacher.

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The guidelines of interview were arranged based on the relationships in the modified didactic triangle. Document analysis was conducted to strengthen the analysis to identify the causes of students' errors in solving HOTS problems based on the components of the didactic triangle. The documents analyzed were books used by students as learning resources.

Data analysis in this study used the stages of analysis according to Miles and Huberman (1994), namely data reduction, data presentation, and conclusion drawing. Data reduction was carried out in this study is the test data of HOTS problems on trigonometry material given to 28 students and 3 out of 28 students were selected as research subjects for further analysis. The data from the work of the research subjects and interviews are presented in the form of descriptions and figures. Furthermore, conclusions were drawn based on analysis of the data that had been presented to obtain the profile of students' errors and their causes viewed from the modified didactic triangle.

## RESULTS AND DISCUSSION

The results of this research included the data from the students' answers in solving HOTS problems, the document analysis, and interviews with students and the teaching teacher. The following is a descriptive analysis of the errors in the answers of the research subject:

1. Subject 1 (S1)

S1 made errors in all problems. Figures 1 to 4 are S1 answers in the problems given. From figure 1, it can be seen that S1 has written what is known and what is asked from the problem correctly, but the solution that S1 done is not correct. S1 devided the height of children by the distance between the children and building A and multiplied by the elevation angle to find the height of building A. S1 also did the same thing to find the height of building B which he only used the information and applied it to simple calculation which is not a correct way to find the answer.

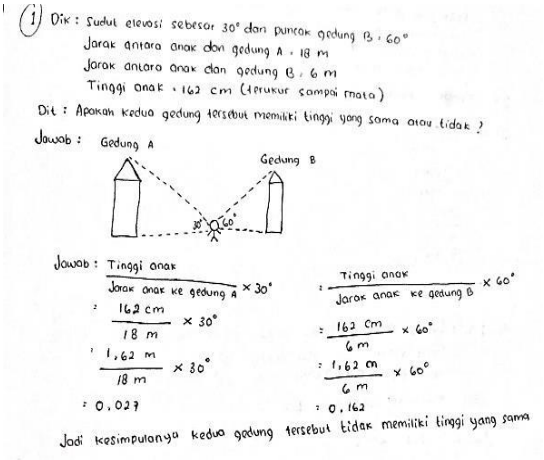


Figure 1. S1's answer to number 1

S1 only used simple operations to solve it, not using the trigonometry concept at all. In addition, the sketch drawn by S1 is also not correct. After the interview, S1 said that he only guessed the formula used because he did not know how to answer the question using the trigonometric concept.

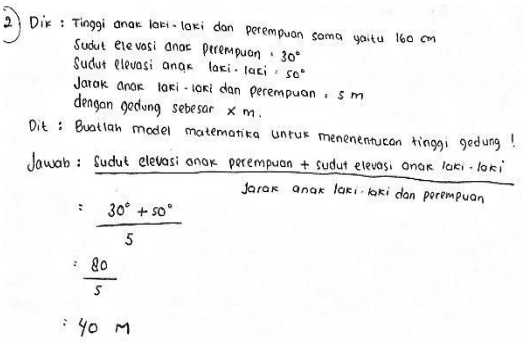


Figure 2. S1's answer to number 2

From Figures 2, it can be seen that S1 already write the information known and what is asked correctly, but the solution is not correct. S1 adds the

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elevation angle of both child and then devided by the distance between two of them. This solution is not match what was asked which is to construct mathematical model to determine the height of the building.

Just like number 1, S1 also did not use any trigonometric concepts in working on number 2. S1 only used simple operations (add and divide) to work on it. The same answer was given by S1 during the interview he only guessed the formulas used because he did not know what trigonometric concept should be used in solving the problem.

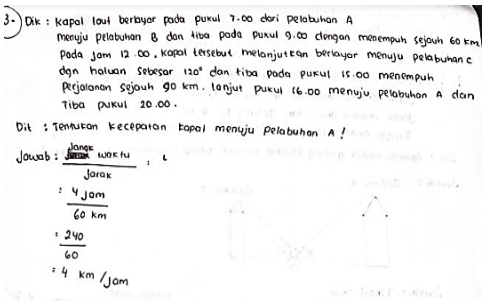

Figure 3. S1's answer to number 3

From Figure 3, it can be seen that S1 write the information known from the problem and what is asked correctly. The solution that S1 done is not correct. S1 did not do the calculation to find the necessary information to solve the problem. S1 has determined the formula to find the speed, but the formula is also not correct. S1 also only devided the time and distance to find the speed of the boat. The information used by S1 in finding speed is information that is already known.

Just like the previous number, S1 did not use any trigonometric concepts in his work. Based on the interview, S1 claimed that he knew the formula that should be used to find speed but he did not know how to find the required value.

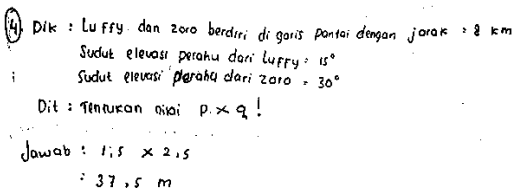

Figure 4. S1's answer to number 4

From Figure 4, it can be seen that S1 has already written what is known and what is asked correctly, but the answer is not correct. S1 only multiplied 1,5 and 2,5 which the values are not known from the problem.S1 did not use any trigonometric concept in solving problem number 4. Based on the interview, S1 said that he did not know how to work on number 4. He also forgot where the value he used was obtained (1.5 and 2.5).

Based on S1's answers, it can be said that S1 has not mastered trigonometric material. This can be seen from all S1's answers that do not use trigonometric concepts. S1 also did not know the right method to work on these problems. This is in line with Hidayati (2020) which stated that one of the factors that cause students' error in solving trigonometry problems is lack of mastery the concept of trigonometry.

S1 also did not interpret all the problems into mathematical models. He only wrote what was known from the problems given. Therefore, it can be said that S1 cannot interpret the problems into the mathematical models. This is in line with Rachman and Saripudin (2020) which stated that in solving trigonometry problems, students' make errors because could not interpreting problems into mathematical model.

2. Subject 2 (S2)

S2 made errors in solving problem numbers 3 and 4 which presented in Figures 5 and 6.

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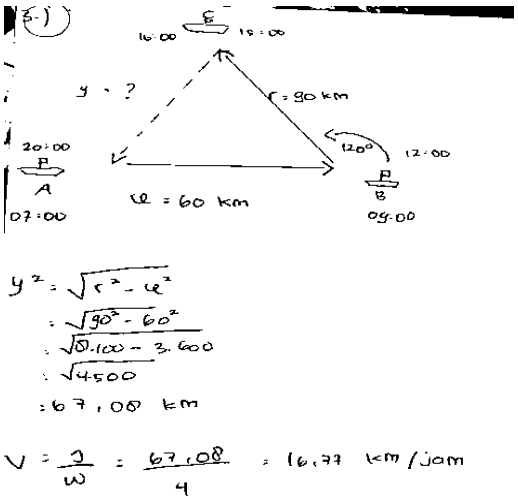


Figure 5. S2's answer to number 3

In figure 5, it can be seen that S2 already drawn the sketch correctly. Although what is asked is not written, but S2 puts a question mark on the value of $y$ in the sketch. This value is the distance between port C to port A which will be used to find the speed of the ship. The solution that S2 did was to find the value of $y$ using squre root of the value of $r^2 - x^2$. He used the Phytagorean theorem to find the distance where the theorem used is not the correct. This theorem should be used on right triangles while the known triangle in the problem is not the right one. After the interview, it was found that S2 considered the distance as easier to find using the Pythagorean theorem than trigonometry.

In figure 6, it can be seen that S2 drawn the sketch correctly. He solved the problem with the correct concept. He used the trigonometric comparison of sines to find the value of $p\sqrt{q}$. It is just that there was a calculation error in rationalizing the fraction of the root form. After the interview, it was found that S2 was not careful in doing the calculation.

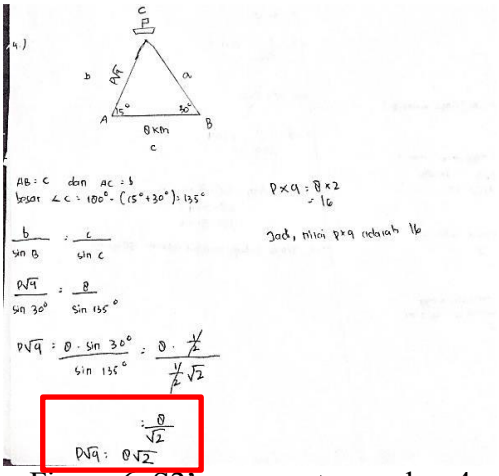


Figure 6. S2's answer to number 4

Based on S2's answers, it can be said that S2 has understood trigonometry material. Errors occur because of incorrect use of concept. This is in line with the result research that conducted by Widodo and Sujadi (2015) which state that the errors occur in solving trigonometry problems is error in using concept. Rohimah and Sufyani (2019) said that in solving trigonometry problems, students tend to find difficulties on applying the trigonometry formulas. Wardhani and Argaswari (2022) also said that in one of the cause of error that made by students in solving trigonometry word problem is lack of ability to find the right strategy.

Errors that S2 made also occur because of carelessness. This is in line the result of research that conducted by Wardhani and Argaswari (2022), Hidayati (2020), Mensah (2017), and Widodo and Sujadi (2015) which found the errors in solving trigonometry problems due to lack of accuracy in calculation.

3. Subject 3 (S3)

S3 made errors in solving problem number 3 and 4 which presented in Figure 7.

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Figure 7. S3's answer to number 3 and 4

From Figure 7, it can be seen that S3 did not work on these number. After the interview, it was found that S3 had not thought of how to work on it. In addition, S3 said that he took too long thinking about how to work on the previous problem so he ran out of time when he wanted to start working on numbers 3 and 4.

Based on S3's answers, it can be said that S3 tends to need longer thinking time to work on these problems. It also can be said that S3 did not understand the problem. He found it difficult to interpret the problems into mathematical model so he did not find the right method to solve it. This is in line with Wardhani and Argaswari (2022) which state that the errors in solving word problem in trigonometry material can be caused by the students' lack of understanding terms in the word problems.

According to the analysis of the answers of the research subjects that have been presented, it can be concluded that the errors made consist of errors in using concepts because do not understand the concept of trigonometry material, calculation due to carelessness, and not answering the given problems because they have not found the right method to work on the problems or do not know how to work on them. This is in line with Cahyani's (2018) opinion which categorized student errors into three, namely: 1) Errors in applying a concept because they do not master the basic material. 2) Errors in the solution operation when not knowing the correct solution method. 3) Careless errors because students forget concepts, formulas, or errors in calculations.

To trace the causes of students' errors viewed from the relationship in the modified didactic triangle, the sourcebook used by students and interviews with research subjects and teacher were analyzed. This analysis cannot be done separately because the didactic triangle focuses on the learning process. Suryadi (2010) said that didactical and pedagogical situations that occur in the learning process cannot be viewed separately because, in reality, these two situations can occur simultaneously. Based on this, the causes of student errors in solving HOTS problems can be identified by matching the results of document analysis, the students' answers in solving HOTS problems, and interviews with the research subject and the teaching teacher.

The document analysis used in this study was the sourcebook used by students to study based on the recommendation of the teaching teacher, namely the High School $10^{th}$-grade Mathematics Book published by the Ministry of Education and Culture of the Republic of Indonesia (Revised Edition 2016). The chapter analyzed is trigonometry. The thing analyzed in this book is the content to find out whether the book used contained complete material, the flow of material presented to see whether the material is presented systematically or not, and examples of problems and exercises whether the questions had the potential to encourage students to think at a cognitive level categorized into HOTS.

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The result of the analysis of the sourcebook shows that the book used by students contained complete material. The flow of material presentation has been presented systematically and does not directly refer to formulas but begins with a stimulus to build concepts first. In addition, sample problems in the book are equipped with alternative solutions. Some sample problems and exercises in the book are also HOTS questions.

Interviews with subjects in this study aim to find out what kind of learning process they experienced. It should be noted that the learning process on trigonometry material at the school where the research took place was carried out in a limited offline manner due to pandemic conditions. Students were divided into 2 groups and entered school alternately so that learning was carried out online (for groups who studied from home) and offline (for groups who studied at school).

The results of interviews with the three research subjects were S1 said that he did not understand the teacher's explanation in the classroom both online and offline. Meanwhile, S2 and S3 felt that they did not understand during online learning but understood a little during offline learning. The three subjects never asked the teacher either in the classroom or in google classroom about the material. S2 said that he lacked confidence to ask because he did not understand, while S1 and S3 did not want to ask. The three subjects said that the teacher never introduced HOTS questions during offline or online learning. The three subjects also stated that they rarely learned this topic from the sourcebook suggested by the teacher because they felt they did not understand. S1 felt that he understood better when the teacher explained directly in the classroom and more often better learned using notes, S2 felt that the sourcebook was too thick so he was lazy to read it and more often learned using friends' notes, while S3 only learned this topic using notes he had. All three also said that online learning has never used video conferencing such as Zoom or Google Meetings.

The interview with the teacher was conducted to confirm the statement of the research subject in the interview. The teacher said that learning was carried out online and offline. Online learning was carried out only using google classroom and teachers upload materials in the form of PowerPoint or learning videos on youtube. Learning has never been carried out using video conferences such as Zoom or Google Meetings. While learning in the classroom was carried out normally the teacher provides material to students.

Teacher preparation before teaching was preparing lesson plans, re-reading the material to be taught, and practicing problems that will be given. She did not prepare any media during teaching because the learning method used was a lecture. She emphasized that this method was used due to the learning time was shortened. This time limitation happened due to the pandemic and also makes her never introduce HOTS to students.

The pandemic condition makes many students have not mastered basic mathematics skills (including S1) such as adding fractions, solving algebraic equations, and others are considered incomplete so the teacher considered students unable to reach the HOTS level. She also said that the pandemic condition makes students have to keep their distance during offline learning so teachers never applied group learning.

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In addition, student responses both offline and online are not much different which were very passive.

The teacher always allowed students to ask questions but only a few students respond and it is always the same students (the teacher did not mention that the three subjects had asked questions in the classroom). In addition, teachers never got questions from students through chat or students came directly to the teacher at school to ask questions about the material.

Based on the results of interviews and analysis of the sourcebook, it is known that students rarely or never study through the sourcebook, even though it contained complete and structured material. In addition, online learning using google classroom makes students not understand the material taught.

Learning in the classroom uses the lecture learning method. The lack of student response in the learning process makes it difficult to create a didactical situation so the learning process feels monotonous. The learning that is carried out by teachers cannot trigger students to learn optimally which causes their HOTS level is not well developed. This is in line with Suryadi's (2010) opinion that varied learning activities can enable the learning process of each student and create a more conducive didactical situation. The contrapositive meaning of this statement is that the didactical situation is not conducive and the learning process by each individual does not occur due to less varied learning activities. Teachers already understand the importance, strategies, and the use of HOTS but are weak in implementing them in learning so the students' HOTS is not well developed (Acharya, 2021; Retnawati et al., 2018). This means that the errors made by students are caused by problems in didactic relationships.

In addition, the interaction between teachers and students is also very lacking. It can be seen from the learning that is carried out forming a passive-student response. Students also do not interact with teachers through social media or outside the classroom to ask questions related to learning. Group learning has never been applied because students are required to keep their distance during the pandemic which causes a lack of pedagogical situation in the classroom. According to Suryadi (2010), a conducive pedagogical situation makes collaborative learning occur both in groups, between groups, and through discussions led by the teacher. Thus, the existence of problems in pedagogical relationships is also a factor that causes students to make errors.

The lack of didactic and pedagogical situations in the classroom leads to a lack of didactic-pedagogical anticipation by the teacher. Teacher preparation in teaching only focuses on conventional learning. This model is not in line with the suggested learning model in the implemented curriculum and cannot improve students' HOTS. Ariyana et al. (2018) said that learning models that can shape scientific behavior and curiosity are Discovery/Inquiry Learning, Problem-based Learning, and Project-based Learning. Therefore, the learning model that used by teachers cannot encourage students' HOTS.

Passive-student responses in learning can be caused by the learning model. Conventional learning will tend to focus on the teacher which causes a lack of responses from students. This lack of responses also makes teachers rarely take didactical or pedagogical

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actions that will create new didactical situations. This is in line with Suryadi's (2010) opinion that the consequences of didactical or pedagogical actions from student responses will result in new situations that are highly dependent on the type of action chosen. Learning that is carried out like this will cause learning difficulties for students.

The lack of mastery of prerequisite material also causes passive-student responses in the learning process. When students do not master the prerequisite material, they likely, students do not understand what is conveyed by the teacher during learning. This needs to be a concern and overcome by providing didactic anticipation of mastery of prerequisite material so that students are not didactically hampered. In line with research conducted by Sakinah et al. (2019) which shows that there is a reduction in student learning barriers after didactical anticipation of the prerequisite material is carried out.

According to Suryadi (2010) in the didactic triangle, the most important role of educators is to create a didactic situation that can encourage students to learn optimally but the pedagogical situation is also important to study so that the quality of learning can always be improved. The three components in learning, namely students, teachers, and materials, are interrelated with each other so that if there is a problem in one relationship, it will very likely have an impact on other relationships. However, the learning carried out by the teacher cannot be seen as entirely inappropriate because the pandemic conditions have also had a major impact on the education field around the world.

## CONCLUSION AND SUGGESTION

Students' errors in solving HOTS-category math problems consist of errors in using concepts, and calculations, and failing to provide answers when solving the given problems. Viewed from the didactic triangle, these errors occur when students do not learn through the resources provided, the learning activities tend to be monotonous, passive-student respond during the learning process, and teacher preparation only focuses on conventional learning. Thus, the errors made by students are caused by the learning experienced by students cannot encourage them to think at the HOTS level.

Based on the findings in this study, it is suggested that teachers should be able to improve the quality of learning such as by using various methods even if the learning is carried out online or offline. In addition, it is suggested to other researchers to do studies about students' error viewed from the learning process that students experienced by using the didactic triangle as a guidelines or other guidelines on different materials or types of problems.

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