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High School Students Mathematical Reasoning Ability in Solving Three Dimensional Problems

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Abstract

The purpose of this study was to describe students' high initial ability, moderate initial ability, and low initial ability mathematical reasoning abilities. The reality in the field shows that students' mathematical reasoning skills in 3D materials are still low and still need to be improved. The subjects in this study were class XII students of SMKF Pekanbaru City totaling 32 students, Riau Province. The research method uses a qualitative descriptive approach. Data collection techniques using written tests, documentation, and interviews. Data analysis using qualitative descriptive analysis by preparing and organizing various kinds of student error data based on each indicator of mathematical reasoning. The results of the research on students' mathematical reasoning ability on each indicator in order are; (1) Presents mathematical statements in pictures 83.3%; (2) Provide reasons or evidence for one or more solutions 55.6%; (3) Make a guess 61.1%; (4) Draw conclusions from statements 63.9%; (5) Checks the validity of an argument 73.6%; and (6) drawing conclusions from several statements 56.5%. The results of this study indicate that mathematical reasoning ability in 3D material in this study 4 indicators are still classified as low. while 2 of them are classified as high.

***Keywords**:* qualitative descriptive analysis; mathematical reasoning; three dimensions

I. Introduction

One of the goals of learning mathematics is to develop mathematical reasoning abilities, communicate, and solve mathematical problems correctly. Mathematics and reasoning are inseparable units because to understand mathematics, reasoning skills are needed (Octriana et al., 2019). Mathematical reasoning also requires sorting out what is important and not important in solving a problem and explaining or providing reasons for a solution (Kusumawardani et al., 2018).

Representing objects in mathematics is very dependent on the level of one's reasoning ability. The level of a person's reasoning ability is the basis that determines whether that person can construct mathematical abilities and knowledge generously. Based on Sun et al. (2005) explaining that explains that a person's reasoning ability must be consistently developed using a variety of contexts, recognizing that reasoning is a basic ability to learn concepts and draw final conclusions. Can be summarized reasoning skills are critical for each student to understand concepts and prove concepts and be able to make conclusions based on the analysis carried out.

However, mathematical reasoning abilities are often found to be low. According to the results of research by Isnaeni et al. (2018) and Indriani et al. (2018) due to low mathematical

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reasoning skills, students need to understand basic concepts and communicate problems in mathematical models. They are not accustomed to working on non-routine problems. Based on the results of observations and interviews by Izzah & Azizah (2019) reasoning abilities in solving math problems still need to improve. In addition, Rosnawati in Nurfitriyanti et al. (2020) explained that the reasoning ability domain of Indonesian students had the lowest average percentage, namely 17%.

The results of Sofyana & Kusuma (2018) showed that the average score of indicators of performing mathematical manipulation was 1.35, the indicator of making conjectures was 1.9, the indicator of concluding, compiling evidence, providing reasons or evidence for the correctness of the solution was 2.2 indicators checking the validity of arguments by 3.4 indicators finding patterns or properties of mathematical phenomena to make generalizations by 1.6. Based on the score of each indicator, mathematical reasoning ability is still relatively low. Teachers generally use conventional learning models (Ardila & Hartanto, 2017). This shows that learning to support mathematical reasoning skills in students has not been realized properly.

The level of students' mathematical reasoning ability can be seen based on indicators of reasoning ability, including (1) Presenting mathematical statements in pictures; (2) Providing reasons or evidence for one or more solutions; (3) Making a guess; (4) Draw conclusions from statements; (5) Checks the validity of an argument (6) Draw conclusions from several statements. Based on Absorin & Sugiman (2018) that students who have high, medium, and low abilities still have difficulty in making generalizations with the lowest average score, drawing conclusions from the statements of an argument has the highest average, and indicators Finding patterns in a mathematical symptom and Formulating a mathematical conjecture medium value. Following research Muslimin & Sunardi (2019) states that indicators of reasoning abilities that are difficult to master are concluding a statement. Kurnia Putri et al. (2019) also explained that students were still in the low category of provide reasons or evidence for one or more solutions. Akbar et al. (2018) also found that it took much work for students to make a guess. This is not easy because students need help to think deductively, so they cannot make generalizations or conclusions and give reasons.

Mathematical reasoning skills must be the focus of attention in learning mathematics at school. Students' poor understanding in mathematics is caused by teachers who focus more on solving procedural and mechanistic problems (Nurhayati et al., 2016). Based on this statement, the main problem is that students' mathematical reasoning skills need to be improved. Drawing conclusions and making statements requires good reasoning. It is supported by (Agustin, 2016). Based on this statement, the main problem that occurs is because the mathematical reasoning skills of students are inadequate. Drawing conclusions and making statements requires good reasoning It is supported by Hidayati & Widodo (2015) and Rezki Afinadhita et al. (2022) that reasoning is an activity of thinking to draw conclusions and build a new statement based on some previously known explanations. Mathematics emphasizes that someone can reason to understand concepts and find solutions.

The third dimension is a math learning material that requires good reasoning skills. The difficulty of dimension 3 material is one of them is drawing a building from a story problem that has no known picture and almost every dimension 3 problem is a description problem that requires reasoning in solving it (Gustiadi et al., 2021).

II. Research Method

The purpose of this study was to describe students' mathematical reasoning abilities. The description presented is that students who have high, medium, and low initial abilities will be compared to the results of the reasoning ability test using a description test instrument. Therefore the type of research used in this study is descriptive qualitative. The subjects

in this study consisted of 35 students in class XII Pharmacy SMKF IKASARI Pekanbaru City who were grouped based on students' initial abilities based on the odd semester midterm exam scores in the 2021/2022 school year. The objects of this study were six students consisting of 2 students with high initial abilities, two with moderate initial abilities, and two with low initial abilities. The selection of students for each category was chosen randomly, each of which amounted to 2 students. The group boundaries are determined according to Afrilia & Fadiana (2020) which are presented based on Table 1. Documentation presented on mathematical reasoning ability to describe students' mathematical reasoning ability is presented with a maximum of 2 questions per subject.

Table 1.
Criteria for students' mathematical reasoning ability

Score	Category
score ≥ 80	High
$65 <$ score < 80	Medium
score ≤ 65	Low

(Afrilia & Fadiana, 2020)

The data collection techniques used were tests, documentation, and interviews. The test questions in this study were valid and adopted from Efendi (2016). The test questions consisted of 6 questions about the description of 3D material that represented each indicator of mathematical reasoning ability in this study. Stated whether the teacher interviewed all students or selected some students. The teacher mentioned whether to interview all students or select some students. While the interview, the researcher chose 6 students, including 2 students with high initial abilities, 2 with medium initial abilities, and 2 with low initial abilities. This was done to collect information and important facts to find out the causes of difficulties students face when solving 3D problems. Data analysis techniques include data reduction, presentation, verification, and conclusions. So that the findings are valid and credible, the research data is processed by triangulating sources and methods. Source triangulation is done by taking two subjects from each category of mathematical ability and comparing the results of the two students to get the same conclusion. At the same time, the triangulation method in this study is to combine test techniques, documentation, and interviews on student mathematical reasoning ability test questions. The interview was conducted to strengthen the answers from the written test results.

III. Results and Discussion

The data in this study includes data on students' mathematical reasoning ability when answering tests on 3D topics. The data is taken through a test instrument. This aims to determine the high, medium, and low categories of students' mathematical reasoning ability. Then the researcher documents the students' written answers. Mathematical reasoning ability is represented in the form of a percentage (%) on each indicator, calculated by the formula based on (Sholehah et al., 2021).

$$p = \frac{\sum x}{\sum x_i} \times 100\%$$

Keterangan:
p : Persentase tiap indikator
$\sum x$: Total Skor yang diperoleh
$\sum x_i$: Total skor maksimal

Students' mathematical reasoning ability in 3D material based on six indicators in six questions. The following is a description of data on mathematical reasoning ability presented in Table 2.

Table 2.
Average of student's reasoning ability indicator

Question number	Indicator	Average (%)
1	Presents mathematical statements in pictures	83,3%
2	Provide reasons or evidence for one or more solutions	55,6%
3	Make a guess	61,1%
4	Draw conclusions from statements	63,9%

Question number	Indicator	Average (%)
5	Checks the validity of an argument	73,6%
6	Draw conclusions from several statements	56,5%

Next, we will present students' initial and mathematical reasoning abilities based on 6 3D problems representing 6 indicators. Initial ability is obtained based on the midterm exam results for the 2021/2022 school year. Meanwhile, the value of mathematical reasoning ability is obtained from the test results of working on 3D material test questions. The 2 abilities are represented based on low, medium, and high. The following is presented in Table 3.

Table 3.
Initial ability and mathematical reasoning ability test results

Student Code	Initial Ability of Students	Score	Mathematical Reasoning Ability Category
SW7	High	60	Low
SW3	High	73	Medium
SW12	Medium	63	Low
SW14	Medium	60	Low
SW1	Low	70	Medium
SW15	Low	77	Medium

Mathematical Reasoning Ability of Students with High Initial Ability

Table 4.
Scores of mathematical reasoning ability test results for students with high initial ability

Question number	Maximum Score	Earned Score	
		SW3	SW7
1	4	4	4
2	4	2	1
3	6	4	3
4	6	6	2
5	4	3	4
6	6	3	4

Based on Table 4, the lowest score obtained by (SW7) is question number 2, with an indicator of providing reasons or evidence for one or more solutions that obtained a score of 1 out of a total score of 6, and question number 4 drawing conclusions from statements only obtained a score of 2 out of a total score of 6. It can be seen that students need to provide explanations related to problems that have been represented in the picture. The question asks for evidence that the AC line is perpendicular to the BDHF plane. To clarify the answers that students have written, researchers conduct interviews. The following is a picture of the answer documentation (SW7) and the results of the interview that has been conducted.

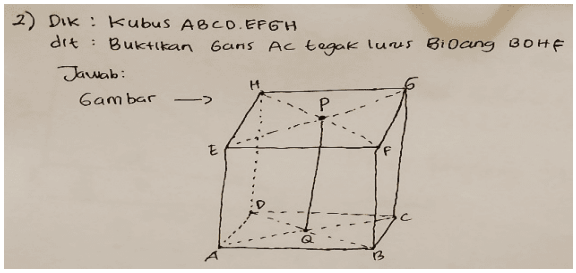

Figure 1. Answer SW7 question no. 2

Researcher : *Gambar yang Anda buat sudah mengarah ke pertanyaan. Tetapi mengapa Anda tidak menjelaskannya menggunakan kalimat? Apa kamu tidak mengerti maksud dari pertanyaannya?*
The picture you created already leads to the question. But why didn't you explain it using a sentence? Didn't you get the point of the question?

SW7 : *Saya mengerti pak, bahwa garis diagonal AC tegak lurus dengan bidang BDHF. Saya juga pernah menjadikan garis PQ sebagai tanda bahwa AC tegak lurus dengan PQ, tetapi saya tidak tahu bagaimana menjelaskannya.*
I understand sir, that the diagonal line AC is perpendicular to the BDHF plane. I've also used the PQ line as a sign that AC is perpendicular to PQ, but I don't know how to explain it.

Based on the documentation of SW7's answers in Figure 1 and the interviews conducted, it can be concluded that the indicator of providing reasons or evidence for one or more solutions still

needs to be completed appropriately. SW7's statement reinforces that students still need clarification about explaining that the diagonal line AC is perpendicular to the BDHF plane. Students also do not understand that AC and BD are the diagonals of the ABCD square, so AC is perpendicular to BD; besides, Point Q is the projection of P on the ABCD plane, so PQ is perpendicular to the ABCD plane. This means that students lack an understanding of the previous materials. According to the research results of Hamsiah et al. (2016) students need help understanding the purpose of the question, so they need clarification about what method is correct to answer the question.

Furthermore, SW7 had high initial ability; the results were low after the test. In question number 4, which is an indicator of drawing conclusions from statements. The following is a description of student answers documented and interviews that have been conducted

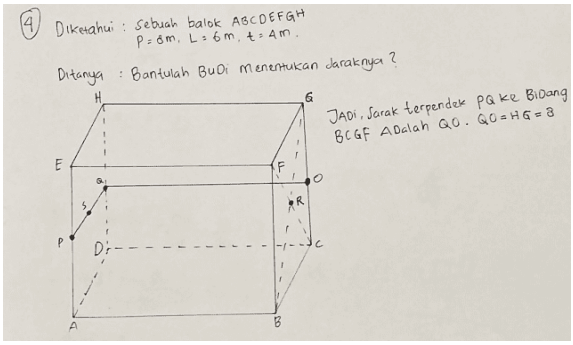

Figure 2. Answer SW7 question no.4

Researcher :*"Bantulah budi menentukan jaraknya?". Apakah kamu paham dengan apa yang ditanyakan soal? Help me determine the distance?". Do you understand what the question is asking?*

SW7 :*paham pak, perintah soalnya membantu budi menentukan jarak terpendek PQ ke BCGF*
understand sir, the question command helps you determine the shortest distance PQ to BCGF

Researcher :*Maksud kamu menentukan titik O ditengah GC bisa dijelaskan?*
Can you explain what you mean by determining point O in the center of the GC?

SW7 :*Karena titik O pada garis GC sudah pada bidang BCGF dan garis PQ dan QO sudah tegak lurus. Jadi saya menjawab QO adalah jarak terhemat pak.*
Because point O on line GC is already on plane BCGF, and lines PQ and QO are perpendicular. So I answered QO is the shortest distance sir.

This is in accordance with the statement expressed by the student that "determining the shortest distance PQ to BCGF" is a fact. However, SW7 could not project the shortest distance between line PQ to plane BCGF correctly. This is consistent with SW7's statement in the interview that "point O on line GC is already in the BCGF plane, and lines PQ and QO are perpendicular to each other." the statement is true if O is the closest point of PQ to the BCGF plane. But the closest distance from PQ to rib FG or from PQ to the BCGF plane is GQ. As a result, the conclusion drawn needs to be corrected. This means that the execution of the concept of distance between lines to the plane needs to be better understood. Research results from Meliyana & Tobing (2017) stated that in their research, the error in determining the distance between the lines and the plane still contained errors due to the inaccuracy of execution based on the applicable concept.

Another high initial ability student is SW3. Based on Table 4. SW3 experienced a change from high to medium. The score obtained by SW3 is perfect, namely on the indicator of presenting a mathematical statement in the form of a picture of problem number 1 and drawing conclusions from the statement of problem number 4. However, in problem number 6, which has the Draw conclusions from several statements indicator, the score obtained by students is low.

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The following are excerpts of SW3's answers to question number 6 and interview results.

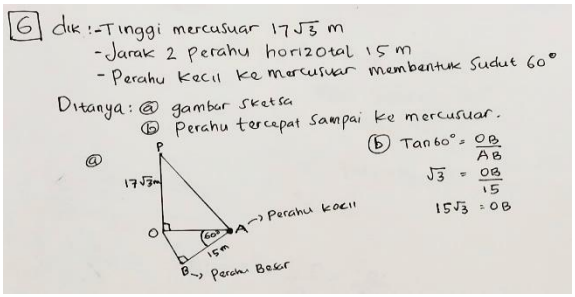

Figure 3. Answer SW3 question no.6

Researcher :*Gambar yang kamu buat sudah benar. Namun boleh kamu jelaskan mengapa kamu meletakkan sudut elevasinya pada OAB?*
Your drawing is correct. But can you explain why you put the elevation angle at OAB?

SW3 :*karena diketahui perahu kecil terhadap mercusuar membentuk sudut 60 derajat, pak.*
since it is known that the small boat against the lighthouse forms an angle of 60 degrees, sir

The indicator concludes several SW3 statements in question number 6, which must also be corrected. Based on the documentation of answers and interviews, the student's error lies in understanding the information contained in the problem, namely, "A person in a small boat saw the top of the lighthouse, so it formed a 60-degree angle so that the 60-degree angle in Figure 3 is the wrong position. In addition, the answers written by SW3 do not provide conclusions even though the calculations made by SW3 need to be corrected. This follows the results of Hidayati & Widodo (2015) that the representation of problems in images still needs to be revised, resulting in calculations being performed automatically incorrectly.

Mathematical Reasoning Ability of Students with Moderate Initial Ability

Table 5.
Scores of students' mathematical reasoning ability test results with moderate initial ability

Question number	Maximum Score	Earned Score	
		SW12	SW14
1	4	3	3
2	4	2	2
3	6	3	5
4	6	5	2
5	4	3	2
6	6	3	2

Based on Table 5, SW 12 obtains the lowest score on questions 2 and 3, each on the indicator providing reasons or evidence for one or several solutions and submitting conjectures. The following is documentation of the completion of SW 12 and the results of the interviews that have been conducted.

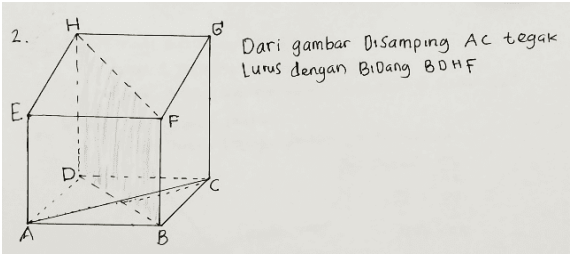

Figure 4. Answer SW12 question no.2

Researcher :*Mengapa kamu tidak menuliskan diketahui dan ditanya? Apakah kamu sudah memahami seluruh informasi pada soal?*
Why didn't you write known and asked? Did you understand all the information in the problem?

SW12 :*Maaf pak saya buru-buru karena sudah hampir habis waktu, pak. Paham pak, soal meminta untuk buktikan AC tegak lurus BDHF.*
Sorry sir, I'm in a hurry because time is running out, sir. Understand sir, the question asks to prove AC is perpendicular to BDHF.

Researcher :*Apakah bisa kamu berikan alasannya?*
Can you give us a reason?

SW12 :*Karena garis AC tegak lurus dengan BD, pak*

Since the line AC is perpendicular to BD, sir

Problem number 2 indicates providing reasons or evidence for one or several solutions. Based on the documentation of SW 12's answers in Figure 4, it can be seen that SW12 can provide one reason or evidence. This was proven based on an interview session conducted with SW12, which stated, "AC is perpendicular to BD," which should not be enough to conclude that AC is perpendicular to the plane of BDHF. Lack of reasons or relevant evidence results in indicators providing reasons or evidence that one or more solutions have yet to be reached. Contradictory to research results, Rosyidah et al. (2021) believe that indicators provide reasons or evidence for one or several student solutions and must be able to provide more than one relevant reason. Vebrian et al. (2021) also explain the causes of students' difficulties raising reasoning abilities, including students who are not used to it solve questions that require high reasoning abilities, such as literacy questions mathematics that is being done and a lack of mastery of the mathematical concepts that have been studied.

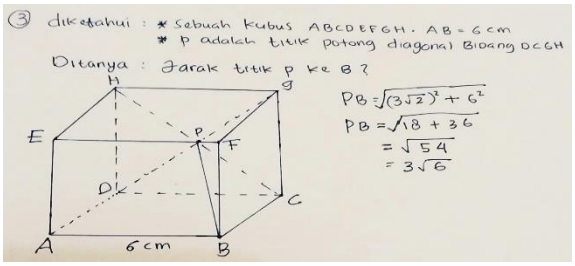

Figure 5. Answer SW12 question no. 3

Researcher :*Berdasarkan gambar yang kamu buat sudah baik, namun bisa kamu jelaskan apa alasan yang mendasari bahwa* $PB = \sqrt{PC^2 + BC^2}$ *(pythagoras) dapat digunakan untuk mencari PB.*
Based on the picture you made, it is good, but can you explain what the underlying reason is that $PB = \sqrt{PC^2 + BC^2}$ *(pythagorean) can be used to find PB.*

SW12 :*Karena PBC adalah segitiga, pak*
Because PBC is a triangle, sir

Researcher :*Betul. Namun dugaan kamu seperti apa sehingga berlaku demikian?*
That's right. But what do you think happened to make this happen?

SW12 :*Tidak tahu, pak*
No idea, sir

Based on SW12's answer to question number 3, the indicator presented a conjecture that showed that students understood the information and questions well. Besides that, it also performs the correct calculations, but it does not explain the likely reason that caused SW12 to calculate using Pythagoras. Based on the SW12 interview session, it was also unable to explain the conjecture that caused the problem to be solved with Pythagoras. When asked about the recognition of SW12 "Do not Know," what are the conjectures so that the Pythagorean calculations can be carried out $PB = \sqrt{PC^2 + BC^2}$. Contradictory to research results, Ardhiyanti et al. (2019) that students can perform calculations correctly and explain conclusions, evidence, and reasons for the calculations performed.

Like SW12, SW14 underwent a change which initially had moderate ability but, on the test results, only obtained a score of 60 which was classified as a low category. SW14 got the best score only on question number 3, with a score of 5 out of 6 indicators proposing conjectures. The lowest score of SW 14 is number 4 on the indicator of drawing conclusions from statements. The following is a picture of the answer documentation (SW14) and the results of the interviews that have been conducted.

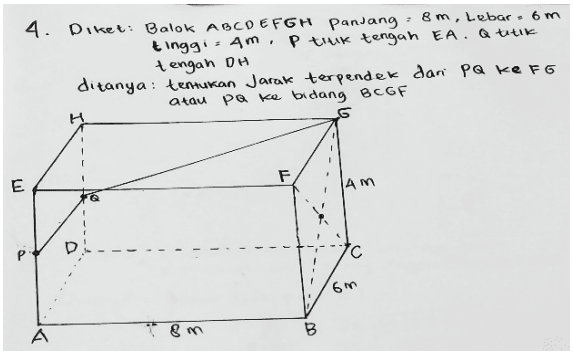

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Figure 6. Answer SW14 question no.4

Peneliti :*Kamu sudah benar dan sesuai dalam membuat gambarnya. Mengapa tidak dilanjutkan ke proses perhitungan? Bisa dijelaskan?*
You are correct and appropriate in making the drawing. Why not proceed to the calculation process? Can you explain?

SW14 :*Maaf pak, saya bingung tentang pertanyaan pada soal "dari PQ ke rusuk FG atau dari PQ ke bidang BCGF"*
Sorry sir, I am confused about the question "from PQ to rib FG or from PQ to field BCGF".

Based on the documentation, SW14's answers have described conditions following the information as known and asked in the questions. However, the calculation process was not carried out by students because students needed help understanding what the questions meant. The students expressed this directly: "I was confused about the questions on questions from PQ to FG ribs or from PQ to the BCGF field." Students do not continue the calculation process because they need to understand the questions, so they fail to conclude from the statements. Relevant to research results Julaeha & Kadarisma (2020) that a result of needing to understand the concept of the problem and resulting in the calculation process not occurring. Meanwhile, according to (Pratiwi & Anita, 2021) the factors, students do not master the concept and only refer to memorizing existing formulas without finding out the origin of the formula, which results in students ignoring basic concepts and lacking mastery of prerequisite material.

Mathematical Reasoning Ability of Students with Low Initial Ability

Table 6.
Score Results te mathematical reasoning ability of students with low initial ability

Question number	Maximum Score	Earned Score	
		SW1	SW15
1	4	3	3
2	4	3	3
3	6	3	4
4	6	5	5
5	4	3	1
6	6	4	5

Based on Table 6. SW1 was unable to complete any of the six questions given. The best score obtained by SW1 is number 4, with the indicator Drawing conclusions from statements, while the lowest is in question number 3, with the indicator making assumptions. The following is an excerpt of SW1 documentation and the results of the interviews that have been conducted.

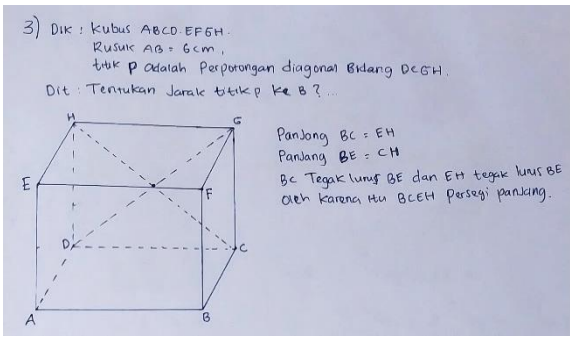

Figure 7. Answer SW1 question no.3

Researcher :*Dugaan yang kamu tuliskan sudah tepat?apakah kamu paham dengan pertanyaan pada soal?*
The conjecture you wrote down is correct? Do you understand the question in the problem?

SW1 :*Paham pak, pertanyaannya adalah jarak titik P ke titik B*
Understood sir, the question is the distance from point P to point B.

Researcher :*Titik P letaknya dimana? Mengapa tidak dituliskan digambar?*
Where is point P located? Why not draw it?

SW1 :*Maaf pak, saya lupa menuliskannya*
I'm sorry sir, I forgot to write it down

Researcher :*Bisa dijelaskan mengapa kamu tidak menghitung jarak titik p ke B?*
Can you explain why you didn't calculate the distance from point p to B?

SW1 :*Saya kurang paham cara menghitung jarak P ke B*
I don't understand how to calculate the distance from P to B

Based on Figure 7. and the interview results, SW1 could describe the situation according to the questions on the problem. SW1 has also been able to write down several conjectures to solve the problem to be solved. However, when they wanted to calculate the distance from P to B, students could not calculate it because they needed to understand what concepts should be used for the needs of the calculation process that should be carried out. The completion step that SW1 should do is to apply the Pythagorean concept $PB = \sqrt{PC^2 + BC^2}$. However, students do not describe which triangles can be formed so that Pythagoras can apply. Based on research results, Rohmah (2020) students need help to project the triangles that must be formed and adjust the questions asked in the questions. According to Ramdan & Lessa Roesdiana (2022) the student had manipulated a mathematical triangle by describing a triangle, but the answer still needed to match the information known from the problem.

Referring to Table 6. the same result also occurred in SW15. The highest scores obtained were in questions 4 and 6, namely on indicators drawing conclusions from statements and from several statements. At the same time, the lowest score is at number 5. The following is an excerpt of the completion of SW15 and the interview results.

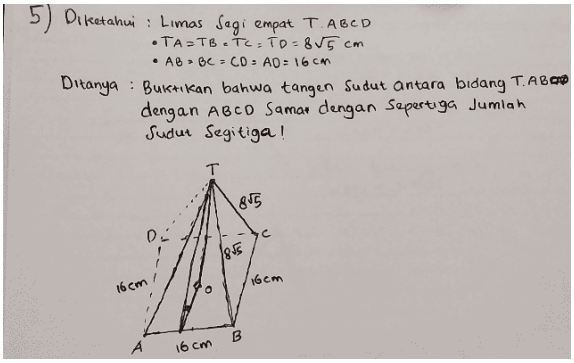

Figure 8. Answer SW 15 question no. 5

Researcher :*Gambar yang kamu buat sudah sesuai dengan informasi pada soal dan diketahui yang kamu tuliskan. Bisa kamu jelaskan mengapa hanya sampai menuliskan gambar saja? Dari permasalahan yang ditanya apa yang tidak kamu pahami ?*
The drawing you made is in accordance with the information in the problem and the known that you wrote down. Can you explain why you only wrote the picture? From the problem asked, what do you not understand?

SW15 :*Saya tidak tahu mengenai tangen, saya tidak ingat bagaimana cara mencarinya.*
I don't know about the tangent, I need to remember how to look it up.

Based on the documentation of SW15 answers, students have written down information known and asked the following questions. The images presented by students are also following the desired questions. However, based on the interview session, they needed to learn about comparing trigonometry concepts. Based on the documentation of students' answers and interview sessions, it can be concluded that knowledge of trigonometry prerequisite material needed to solve 3D problems has yet to be well mastered. This follows research by Gustiadi et al. (2021) that the cause of students' inability to solve 3D problems did not understand the trigonometry prerequisite material.

IV. Conclusion

Based on the results and discussion of the 6 indicators, 4 indicators of mathematical reasoning ability are still lacking, including (1) Providing reasons or evidence for one or more solutions that students do not understand the previous material, (2) compiling arguments, categorized as low because it requires knowledge including understanding of prerequisite material

(3) Make a Guess, the case is that students are able to perform calculations but are unable to conjecture why the calculation steps using Pythagoras are carried out, (4) Drawing conclusions from statements, categorized as low due to the execution of mathematical concepts is still not correct as a result it is wrong to draw conclusions. At the same time, the 2 indicators of Presenting mathematical statements in the form of images and Checking the validity of an argument are better. At the same time, the 2 indicators of Presenting mathematical statements in the form of images and Checking the validity of an argument are better. On average, students are able to present mathematical statements through images. This is evidenced by the 83.3% obtained for the indicator of presenting mathematical statements through images. Checking the validity of an argument is better, as evidenced by the 73.6% obtained students have been able to overcome it.

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