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Students' Mathematical Reasoning Skills in Solving Mathematical Problems

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ABSTRAK

Materi matematika akan mudah dipahami melalui penalaran dan keterampilan bernalar itu dapat dilatih melalui pembelajaran matematika. Namun, masih banyak siswa yang tidak memiliki kemampuan penalaran yang baik. Penelitian ini bertujuan untuk menganalisis kemampuan penalaran matematis siswa kelas XI SMA trigonometri dalam menyelesaikan masalah matematika. Penelitian ini merupakan penelitian deskriptif kualitatif. Partisipan dalam penelitian ini adalah 2 mahasiswa yaitu mahasiswa 1 (S1) dan mahasiswa 2 (S2) yang dipilih secara purposive sampling. Instrumen yang digunakan untuk mendalami keterampilan penalaran matematis ini adalah tes tertulis dan wawancara. Triangulasi metode digunakan untuk memvalidasi data. Hasil penelitian menunjukkan bahwa S1 mampu memenuhi indikator penalaran dalam mengajukan dugaan, memprediksi jawaban dan proses penyelesaian, melakukan manipulasi matematika dan menyimpulkan kalimat pada akhir penyelesaian. S2 mampu memenuhi indikator penalaran dalam mengajukan dugaan dan memprediksi jawaban serta proses penyelesaiannya. Namun, S2 kurang mampu melakukan manipulasi matematika dan kurang mampu menyimpulkan kalimat di akhir suatu penyelesaian.

ABSTRACT

Mathematical material will be easily understood through reasoning and that reasoning skills can be trained through mathematics learning. However, there are still many students who do not have good reasoning skills. This study aims to analyses the mathematical reasoning skills of class XI students of Senior High School on trigonometry in solving mathematical problems. This research is a qualitative descriptive study. The participants of this study were 2 students, namely student 1 (S1) and student 2 (S2) who were selected by purposive sampling. The instruments used to explore this mathematical reasoning skill were written tests and interviews. Triangulation method was employed to validate the data. The results showed that S1 was able to meet the reasoning indicator in proposing conjectures, predicting the answers and the solution process, performing mathematical manipulation and concluding sentences at the end of a completion. S2 was able to meet the reasoning indicator in proposing conjectures and predicting the answers and the solution process. However, S2 was less capable in performing mathematical manipulation and less capable concluding sentences at the end of a completion.

1. INTRODUCTION

Mathematical reasoning is essential in the process of learning mathematics since mathematics is a science that is obtained through reasoning. Mathematics as a science that requires reasoning in its thinking process (Diniyah et al., 2018; Kadarisma et al., 2019). One of the objectives of appropriate high school's (SMA/MA) mathematics learning is that students are expected to have the ability to use reasoning on trait patterns in constructing arguments, formulating evidence, or describing mathematical arguments and statements (Albay, 2019; Djam'An et al., 2021). Mathematical reasoning is also included in one of the assessment indicators tested in PISA (Hidayah et al., 2021; Pratiwi, 2019). It is in accordance with previous research that state mathematical reasoning skill is very important to help students in the process of

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understanding, solving a problem, drawing conclusion, proving a statement, and solving problems in mathematics (Sumartini, 2015).

Ability conceptual understanding is one math skill the important thing is mastered by students in learning, giving understanding of things that need to be seen careful in learning. Consequence from that the learning process must be paying special attention to the situation student abilities. Learning is not just about acquisitions; it is meant to be about participation. And there is an increasing emphasis on catering effectively to students from diverse backgrounds and different abilities within the classroom without bothering them (Smieskova, 2017; N. S. Wahyuni & Widayanti, 2020). The facts on the ground show that the learning process in the classroom still tend to emphasize knowledge of concepts learned, while the student's ability understand conceptually only given the opportunity in time which is very short so that students often make mistakes in solve the given problem. One example is in Trigonometry learning. Trigonometry is a material that is considered difficult by most students in mathematics subjects so that students experience confusion in its application (Usman & Hussaini, 2017; N. S. Wahyuni & Widayanti, 2020).

In fact, students' reasoning skill is still low. This is in line with the results of PISA study which decreased compared to 2015. The value decreased from 386 to 379. The results of study (Trends in International Mathematics and Science Study) also showed that Indonesia was in a low position, ranked in 44th out of 49 countries with an average score of 397 out of an average International score of 500 (Lara-Porras et al., 2019; Umbara & Suryadi, 2019). The lack of students' mathematical reasoning skills was also reinforced by the results of previous research which reported that the level of students' reasoning skills was still low in answering reasoning questions (Izzah & Azizah, 2019). Also, in general, students do not understand the questions and have good reasoning skills. Reasoning is a process or a thinking activity to draw a conclusion or thinking process in order to make a new statement that is true based on several statements whose truth has been proven or assumed previously (Adamura & Susanti, 2018; Lemmer et al., 2020). Meanwhile, previous study stated that mathematical reasoning is the basis of mathematics in drawing conclusions from understanding the concepts, ideas, and their relationships to solve mathematical problems (Gravemeijer et al., 2017; E. S. Wahyuni et al., 2019). Thus, mathematical reasoning skill is an activity or process of thinking on a mathematical problem to draw conclusions from new statements that are true.

Students have four important components in mathematical reasoning, namely communication, basic mathematical skills, connections, and logical thinking (Kurniawati et al., 2021; Sumarsih et al., 2018). These components can be used to measure the reasoning skills, whether they are good and they can make it easier for students to understand mathematics (Supriadi et al., 2021; E. S. Wahyuni et al., 2019). Reasoning skills in proposing conjectures is related to connecting mathematical problems with their own words orally or written by mentioning known things and questioning the problems. Predicting the answers and solution process concerns with illustrating what is known and asked in the form of pictures (Fatimah et al., 2019; Kurniawati et al., 2021). The highest level of mathematical reasoning skills that students can have can solve mathematical problems better (Lestary et al., 2019; Novitasari et al., 2021).

Many students make mistakes at the stage of mathematical manipulation (Rahmawati & Permata, 2018; Wati & Sujadi, 2017). In addition, in explaining the conclusions, students often use their own language and present it orally. This is in line with previous study who stated that students' problem solving allows the teachers to see the stages of students' argumentation and find out the difficulties or obstacles to develop conceptual understanding (Novitasari et al., 2021). Furthermore, this is also in line with previous study that stated that mathematical material will be easily understood through reasoning and that reasoning skills can be trained through mathematics learning (Supriadi et al., 2021). Thus, teachers can predict each student's mathematical reasoning skills to help students improve and develop it. Based on this description, this article explains the students' mathematical reasoning skills in solving mathematical problems. This study aims to analyses the mathematical reasoning skills of class XI students of SMA Negeri 2 Salatiga on trigonometry in solving mathematical problems.

2. METHOD

This study is a qualitative research (Creswell, 2013; Mayer, 2015) conducted at SMA Negeri 2 Salatiga with descriptive data in the form of a description of students' mathematical reasoning skills in solving mathematical problems in trigonometry. The test was given to 31 students of class XI MIPA 1. The results of students' answers were analyzed based on the indicators of mathematical reasoning skills. Then, the answers from two students were chosen for providing information that could be studied further. Two students were, then, selected to be interviewed. The instruments used in this research were the main instrument which was the researcher himself and the supporting instruments which were in the form of a

written test (reasoning skills) and interview guidelines. The tests and interview guidelines were validated by experts and proved that these instruments can be used to measure mathematical reasoning skills. This study used a triangulation method in which the results of the analysis of the answer sheets and interviews of the two students were compared to determine the validity of the data. The test consists of 1 question based on the indicators of mathematical reasoning. The first reasoning indicator is in proposing conjectures, which is indicated by the ability to state what is known and asked in the question. The second reasoning indicator is in predicting the answer and solution process, which is indicated by the ability to reveal important information about a mathematical problem into the picture. The third reasoning indicator is in performing mathematical manipulation, which is indicated by the ability to use the right formula and perform calculations. The fourth reasoning indicator is drawing conclusions from the statement, which is indicated by the ability to conclude the final result.

3. RESULT AND DISCUSSION

Result

The mathematical reasoning skill test on the trigonometric topic that students did can be seen in Figure 1.

> Lia was asked to calculate the height of the flagpole. First, to find out the distance, she stood close to the flagpole. Lia tied a rope to the flagpole and then pulled (perpendicular to the flagpole) to the limit where she stood, and the result of the calculation was 9 m in length. Then, while standing, Lia checked the end of the flagpole using a clinometer to determine the angle. If the angle formed is 60° and Lia's height from the eyes to soles is 150 cm. how high is the flagpole? ($\sqrt{3}\approx1,7$)

Figure 1. The Item of Solving Problems

The following are the results of the study and discussion, the mathematical reasoning skills of high school students which include reasoning skills in proposing conjectures, predicting answers and solution process, performing mathematical manipulations, and drawing conclusions.

Reasoning skills in making conjectures

Students are considered to be able to meet the reasoning indicators in proposing conjectures well when they are able to write down what is known and asked according to the information provided in the questions. Writing the facts from questions is very important to minimize student errors since it affects the next stage. Reasoning skills in proposing conjectures can be seen from the answers of S1 and S2 in Figure 2 and Figure 3.

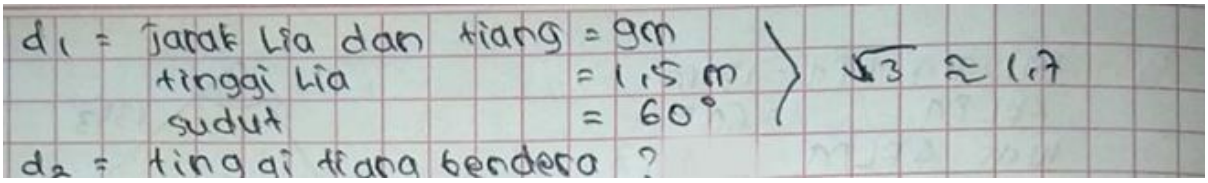

Figure 2. The Answer Result of S1

As seen in Figure 2, S1 was able to identify important information in the question well, which was shown by writing down what was known in the question in the form of Lia's distance to the pole, Lia's height, and the elevation angle. S1 was also able to state what was being asked in the question which is the height of the pole. The summary of the interview's results with S1 regarding the steps for working on the questions shows that S1 understands the questions well. It is indicated by S1's ability to explain what is known and asked in the questions. Based on the interview's results, S1 is able to explain the important information contained in the questions according to the written answers.

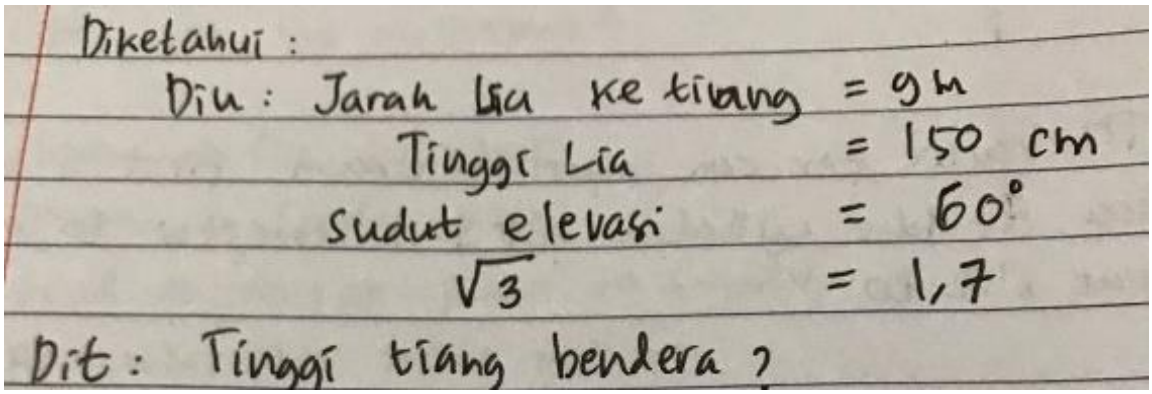

Figure 3. The Answer Result of S2

Figure 3 shows that S2 was able to identify important information in the question well, which was shown by the ability in writing down what was known in the question in the form of Lia's distance to the pole, Lia's height, and the elevation angle. Furthermore, S2 was also able to state what was being asked in the question which is the height of the pole. The summary of the interview's results with S2 regarding the steps for working on the questions shows that S2 understands the questions well. It is indicated by S2's ability to explain what is known and asked in the question. Based on the interview's results, S2 is able to explain the important information contained in the questions according to the written answers.

Reasoning skills in predicting answer and solution process

Students are considered to meet the reasoning indicators in estimating answers and the solution process well when students are able to sketch pictures of flagpoles and the distance of the people correctly and their sizes. Most of the students who were given the test were able to sketch and explain the pictures well, although there were still some students who were correct in sketching but were still confused in making symbols or numbers to clarify the picture. The ability of reasoning in predicting answer and solution process can be seen in the S1's and S2's answers in Figure 4 and Figure 5.

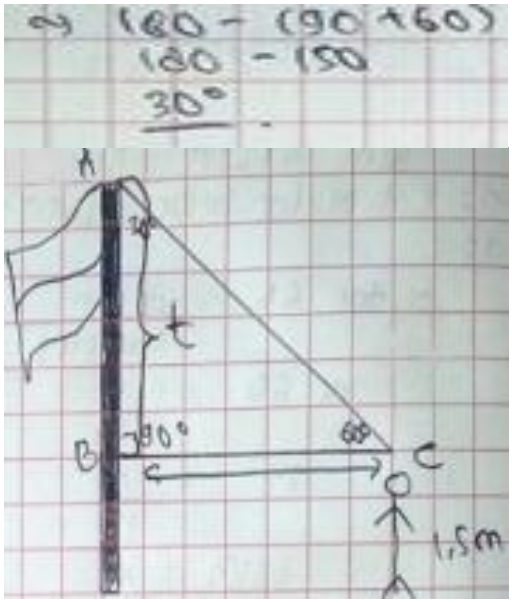

Figure 4. The Answer Result of S1

In Figure 4, S1 was able to meet the reasoning ability in predicting the answer and the solution process, indicated by the ability to illustrate the right triangle by applying the relevant and right information from the question. The summary of the interview's results with S1 regarding the steps for working on the questions is as follows: 1) S1 is able to explain the illustrations according to the information obtained from the questions. 2) S1 is able to explain the location of the angles and sides according to the information in the question. Based on the interview's results, S1 is able to explain the steps in working on the questions well and in accordance with the written answers.

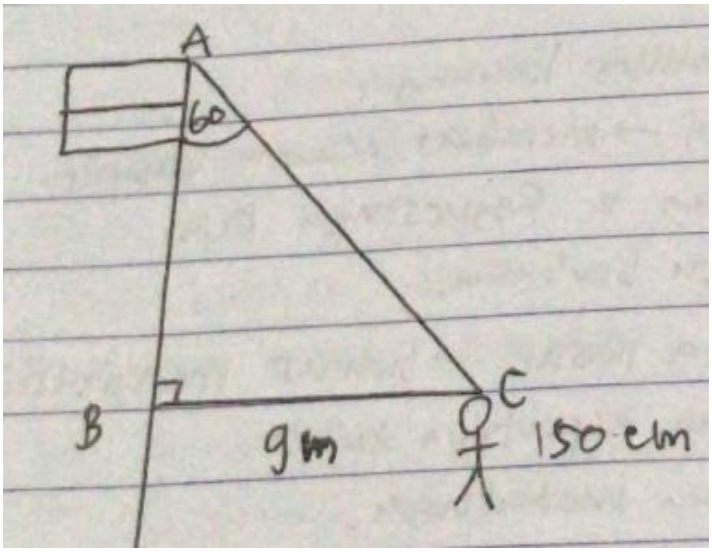

Figure 5. The Answer Result of S2

In Figure 5, S2 was able to meet the reasoning skills in predicting the answer and solution process, indicated by the ability to illustrate a right triangle and include the information contained in the question, but it was not quite right because S2 misplaced the elevation angle on the picture. The summary of the interview's results with S2 regarding the steps for working on the questions is as follows: 1) S2 is able to explain the illustrations according to the information obtained from the questions. 2) S2 is not able to explain the location of the angle according to the information in the question. Based on the interview's results, S2 is barely able to explain the steps in working on the questions in accordance with the written answers.

Reasoning skills in performing mathematical manipulation

Students are considered to meet the indicators of reasoning ability in performing mathematical manipulations well when they are able to use the right formula and do the calculations correctly. Students in solving the problem do not plan problem solving by making mathematical models or determining the formula. Thus, the students do not plan problems properly because they do not know the correct solution strategy. Reasoning skills in performing mathematical manipulation can be seen in the answers of S1 and S2 in Figure 6 and Figure 7.

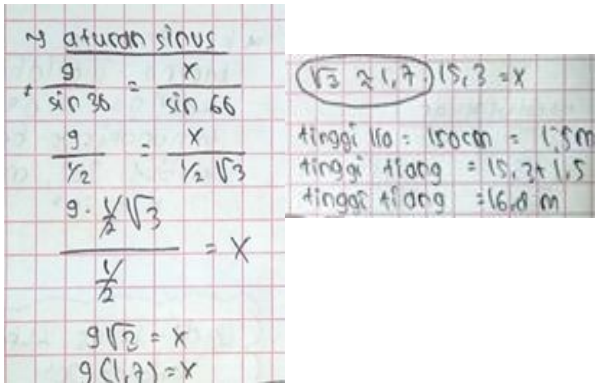

Figure 6. The Answer Result of S1

In Figure 6, S1 was able to meet the indicators of reasoning skill in performing mathematical manipulations well, which was indicated by the ability to write down the steps of completion and calculations correctly. S1 used sine rule to find one side of the triangle in order to find the height of the flagpole. The summary of the interview's results with S1 regarding the steps for working on the questions shows that S1 understands the questions well. It is indicated by S1's ability to explain the formula and the steps for solving the problem correctly. Based on the interview's results, S1 is able to explain the steps in working on problem solving problems properly and in accordance with written answers.

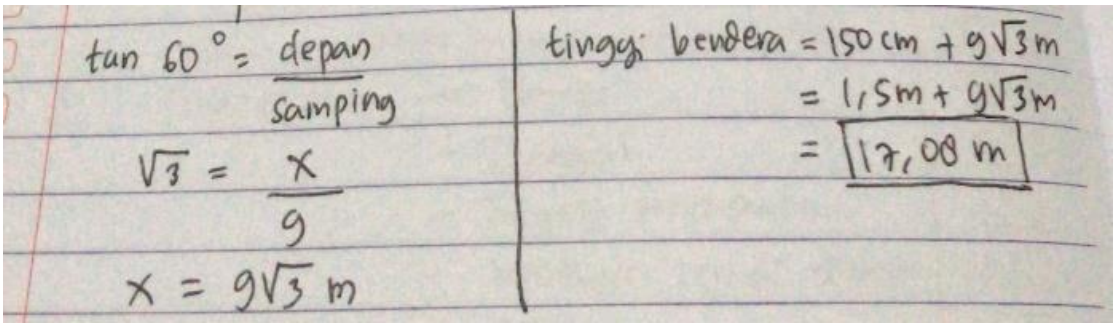

Figure 7. The Answer Result of S2

In Figure 7, S2 is still lacking in the reasoning ability in performing mathematical manipulations, which S2 got wrong in calculations. An error was made when multiplying 9 and 3 so that when the results were added to 1.5 m the result was not 17.8 m but 16.8 m. The summary of the interview's results with S2 regarding the steps for working on the questions shows that S2 understands the questions well. However, S2 is less accurate in calculating the flagpole's height. It is indicated by S2's ability to explain the formula but not the steps for solving the problem correctly. Based on the interview's results, S2 is barely able to explain the steps in working on problem solving problems properly and in accordance with written answers.

Reasoning skills in drawing conclusion from statements

Students are considered to be able to meet the indicators of reasoning skills in drawing conclusions from statements well when they are able to make the concluding sentence from the correct answers. Reasoning skills in performing mathematical manipulation can be seen in the answers S1 and S2 in Figure 8 and Figure 9.

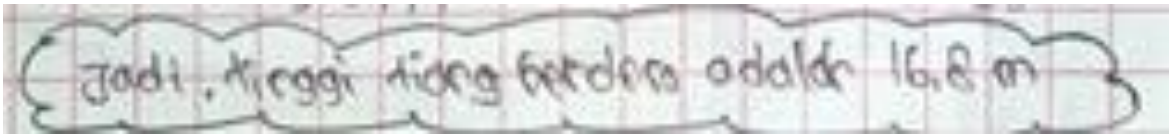

Figure 8. The Answer Result of S1

In Figure 8, S1 is able to meet the indicators of reasoning skills in drawing conclusions from statements well which is shown by the ability to make conclusion sentences from the results obtained. The summary of the interview's results with S1 regarding the steps for working on the questions show that S1 understands the questions well. It is indicated by S1's ability to explain the conclusion sentences made in the final result of the questions. Based on the interview's results, S1 is able to explain the conclusions of the final answer in accordance with the written answer.

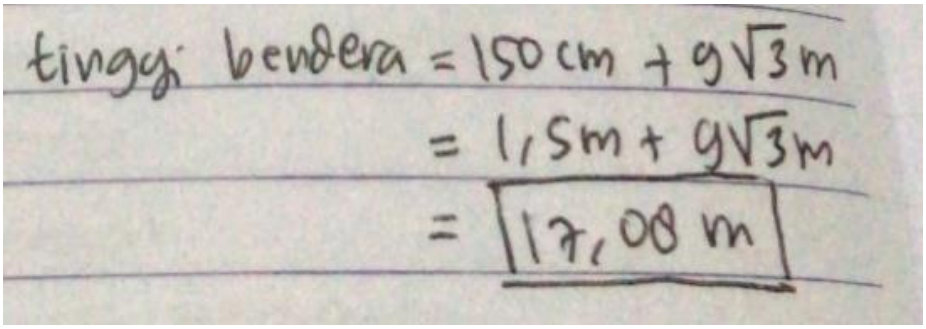

Figure 9. The Answer Result of S2

In Figure 9, S2 did not make the final concluding sentence at the completion but only provided a conclusion with a box mark on the answers obtained. It shows that S2 is still lacking in the indicators of reasoning skill specifically in drawing conclusions from statements. The summary of the interview's results with S2 regarding the steps for working on the questions shows S2 understands the questions well but S2 is not able to explain the final conclusions properly according to the written answers.

Discussion

Students, in comprehending the problem, did reasoning activities by proposing conjectures, in which S1 and S2 were able to express important information in the problem well, which was indicated by their ability in writing down the information asked and known. This finding is in line with previous study that a person is considered to master the facts if he can write down the facts and use them correctly (Shadiq & Mustajab, 2011). Furthermore, previous study states that the students can comprehend the question by identifying the facts or information provided, what is known and is asked in the question (Musser et al., 2011). S1 and S2 in predicting the answer and the solution process were able to represent the right triangles correctly. S1 was able to convey the important information about the problem into the picture well, but the S2 made a slight mistake in placing the elevation angle in the picture. This finding is in accordance with study of previous study that representation has an important role in solving mathematical problems, namely to convert abstract ideas or ideas into real concepts, as in the form of pictures, symbols, words (verbal), graphs, tables, and concrete objects (Mustangin, 2015). Similarly, previous study reported that representation is needed by students to communicate mathematical ideas from the abstract to concrete ones, to make it easier to understand (Effendi, 2012).

In performing mathematical manipulations, S1 was able to do reasoning activities well, indicated by the ability in solving the problem in a directed manner by arranging the solution steps correctly using the sine comparison formula. Meanwhile, S2 solved the problem well by using the tan ratio, but was less precise in the calculations. It is in accordance with the finding of previous research which states that errors in the step of solving problems can be in the form of errors in the use of equations, formulas, or errors in calculations. The mistakes are often related to problem solving steps involving arithmetic operations in algebraic form. At the stage of drawing conclusions from the statement, S1 was able to provide conclusions in a form of sentence at the end of the completion. Meanwhile, S2 was also able to make conclusions but less precise. S2 only put a box mark on the obtained final answer. This is in accordance with the opinion of previous study that state students have difficulty in solving problems so that they do not get the expected answer to the question and consider the results of the calculation as the final answer to the question (Musdhalifah et al., 2013).

Another study shows that when understanding the problem, the reasoning activity analyzes the problem: ST (high ability students), SS (medium ability students), and SR (low ability students) revealed important information of the problem well; ST could represent the relevant right triangles, but SS and SR could not; ST identified the concept of tangent trigonometry, while SS and SR identified sine rule (Aminah & Kurniawati, 2018). When planning the problem solving, reasoning activities use connections: ST could connect it with trigonometric comparison of tangents, while SS and SR connected it trigonometric comparison of sine rule. When carrying out the problem solving plan, the reasoning activity implements the strategy: ST used the settlement procedure by setting the solution steps in a directed manner and the calculation was correct, but SS's and SR's calculations were incorrect; ST and SS reviewed the chosen strategy by checking the calculation or formula, but SR did not. When re-examining, the reasoning activity reflects the solution: ST and SS did not write down the conclusion of the solution, but they could interpret the solutions verbally due to unfamiliarity; ST and SS could consider the appropriateness of the solution, but SR could not.

Researcher found the different result which conducted in previous study. The previous study focuses on mathematics reasoning skills based on gender (Prajono et al., 2021). Overall, in previous study found that male and female students' mathematics reasoning skills in solving trigonometry problems was low. Specifically, male and female students' skills in finding a relationship pattern, proposing a conjecture, and generalizing the statement were also low. Only in verifying the truth of an argument, male and female students' skills were moderate. Furthermore, the mathematics reasoning skills of male and female students did not differ significantly. Moreover, male and female students' skills to find a relationship pattern, propose a conjecture, verify the truth of an argument, and generalize the statement were also not significantly different. Therefore, overall, they had the same opportunity to enhance or improve their mathematics reasoning skill. Based on the description of the research, the students have tendency to solve a problem, specifically trigonometry, begins with doing inductive reasoning and then uses deductive reasoning in solving the problem (Christina & Adirakasiwi, 2021; Wijaya, 2018). This finding is in line with the results of previous research that students construct mathematical knowledge by using an inductive mindset (Sadieda, 2019). For instance, learning activities can begin with presenting some examples or observed facts, making the list of traits, estimating the possible results, and then the students can be directed to make the generalization deductively. Furthermore, they can possibly be asked to prove the obtained generalization deductively. In general, in problem solving, students use inductive-deductive mindset. In problem solving, it sometimes only uses either inductive or deductive mindset, but many problems require

both inductive and deductive mindset consecutively. In training students in improving their reasoning abilities, it is hoped that in the future the teacher can provide questions in various forms of reasoning so that students are accustomed to working on problems in various ways and give students the freedom to work on problems in their way, so that students can practice their reasoning skills better. This study still have limitation especially in part of subject that only involving student in one Senior High School. It is hope future researcher can improve by deeper analysis related to students' mathematical reasoning skills in solving mathematical problems.

4. CONCLUSION

In comprehending the problem, S1 and S2 can meet their reasoning skills in proposing conjectures well, indicated by their ability to write down important information in the problem. S1 and S2 were able to meet the reasoning skills in predicting the answers and process solutions well, indicated by the ability to illustrate the right triangles. Based on the results of the analysis of the difficulties of high school students in solving problems related to with trigonometry material, it is obtained that students with high abilities are less in making mistakes than students with moderate and low abilities. If seen From the indicator of problem solving ability, students have not mastered the indicator carry out the plan of completion and review. Mistakes made by students with high and moderate abilities are dominated by a lack of student accuracy when perform the calculation process with the different types of errors made, and when draw a conclusion.

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