



Analysis of Students' Mathematical Thinking Skills in Trigonometry Learning through a Digital Worksheet Assisted by Virtual Reality

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ABSTRACT

Mathematical thinking skills are skills that students need to master, particularly in trigonometry. This study aims to analyze and describe students' mathematical thinking skills in trigonometry learning through Digital Worksheet assisted by Virtual Reality. The method used was qualitative descriptive. The research subjects consisted of 32 tenth-grade students at SMA N 1 Belitang. The research procedure consisted of three stages: preparation, implementation, and the final stage. Data were collected through Digital Worksheet assisted by Virtual Reality, written tests, and interviews. Data analysis was conducted in three stages: data reduction, grouping the data based on four indicators of mathematical thinking skills, and presenting the data based on the Digital Worksheet assisted by Virtual Reality, written tests, and interviews, followed by drawing conclusions. The results of using a Digital Worksheet assisted by Virtual Reality in the specializing activity showed that students were able to identify and explain known and requested information. In the generalizing activity, students were able to transform contextual situations into right triangles. In the conjecturing activity, students were able to make conjectures about the appropriate trigonometric ratios to solve problems. In the convincing activity, students were able to prove their conjectures through calculations and draw conclusions. Based on the written test results and interviews, 14 students with very good skills were able to accurately meet all four indicators of mathematical thinking, 17 students with good skills were able to meet all four indicators although still some errors caused by rushing and a lack of attention to detail, and 1 student with fairly good skills was better able to demonstrate the specializing indicator but still experienced difficulties with the generalizing, conjecturing, and convincing indicators. The results of this study indicate that Digital Worksheet assisted by Virtual Reality in trigonometry learning to support students' mathematical thinking skills.



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Introduction

Trigonometry is one of the key topics in mathematics that students must master, as it is a requirement for graduation (Madadina et al., 2024; Hidayat et al., 2023; Maghfiroh et al., 2024). Furthermore, trigonometry integrates algebraic, geometric, and visual reasoning, making it a crucial component of the high school mathematics curriculum (Obeng et al., 2024). Learning trigonometry requires mathematical thinking skills because the process of understanding and solving trigonometric problems involves how students comprehend concepts and how they think when determining solutions (Maghfiroh et al., 2024). Developing students' mathematical thinking skills is a crucial aspect of mathematics education that goes beyond a focus on problem-solving procedures (Jamiludin, 2025). Mathematical thinking skills form the foundation for students' understanding of concepts and their skills to solve various mathematical problems (Monteleone et al., 2023; Adnan et al., 2024; AlAli et al., 2023). Mathematical thinking skills enable students to solve various problems, so it is important to position them as one of the approaches to learning mathematics (Shidqiya & Sukestiyarno, 2022; Ferdianto et al., 2025).

According to Lorenza et al. (2024) and Ibrahim et al. (2023), mathematical thinking skills consist of four indicators: specializing, generalizing, conjecturing, and convincing. Specializing is the process of understanding, identifying, and analyzing problems. Generalizing is the process of discovering patterns or relationships within problems to form mathematical models. Conjecturing involves making predictions based on observed patterns. Convincing is the process of providing reasons and evidence to prove the validity of the predictions or solutions obtained. However, the results of various studies indicate that students' mathematical thinking skills remain at a low level (Singh et al., 2024; Singh et al., 2022). This low level of mathematical thinking is evident in students' difficulties with logical reasoning and solving various mathematical problems (Jawad et al., 2021). This occurs because learning remains procedural in nature and does not sufficiently foster the development of mathematical thinking processes (Afifah et al., 2026). These low levels of mathematical thinking ability are also evident in abstract topics such as trigonometry, which involves concepts of trigonometric ratios, trigonometric functions, and their application to contextual problems (Basir et al., 2024). This is evident from students' low performance in solving trigonometry problems particularly those involving angles of elevation and angles of depression with an average score of 46.92%, indicating that many students have yet to master trigonometry concepts (Sabanal & Guevara, 2025).

Several factors contributing to students' low mathematical thinking skills in trigonometry include the abstract nature of the subject matter, teacher-centered learning, and an emphasis on rote memorization rather than conceptual understanding (Adhikari & Subedi, 2021). Furthermore, when studying trigonometry, students still struggle to translate information from contextual problems into mathematical models (Obeng et al., 2024). This finding is supported by Fauzi et al. (2022), who noted that students have difficulty transforming information from trigonometric problems into appropriate mathematical models. As a result, students still struggle to solve trigonometry problems, making effective trigonometry learning essential.

Effective trigonometry learning must be designed to address various factors that contribute to students' low mathematical thinking skills, particularly abstract concepts, teacher-centered learning, and students' difficulty in transforming contextual problems into mathematical models. One alternative learning approach that can be implemented is teaching trigonometry using Digital Worksheet assisted by Virtual Reality. Digital worksheets are a type of digital learning material that is used in practice to support learning (Audina et al., 2025).

Digital worksheets allow for the integration of various multimedia elements and interactive activities that can encourage students' active engagement in the learning process (Satria et al., 2025; Lestari et al., 2022; Chen et al., 2022). Interactive digital worksheets are needed to improve students' critical thinking skills and support challenging and meaningful learning activities (Utaminingsih et al., 2024). Virtual Reality is a technology that creates a computer-generated simulated environment that feels as if it were real through devices such as Virtual Reality headsets (Lara-Alvarez, 2023). In mathematics education, Virtual Reality can help students visualize abstract concepts through immersive and interactive learning experiences (Tsaaqib et al., 2022; Orhak & Çağıltay, 2024). Virtual Reality can also help students create representations through virtual environments that allow them to observe and explore mathematical objects or situations visually and spatially (Assidiqi & Sugiman, 2026). Additionally, the integration of Digital Worksheets and Virtual Reality can create a more student-centered learning experience (Istihapsari & Kusuma, 2026).

Several previous studies have utilized technology including worksheets and virtual reality in learning. Tsaaqib et al. (2022) employed a Posttest-Only Control Design and demonstrated that the use of virtual reality enhances students' motivation and mathematics learning outcomes. Oktaviyanthi & Sholahudin (2023) developed PhET-assisted trigonometry worksheets to stimulate students' adaptive thinking skills. Audina et al. (2025) employed a development study to create an inquiry-based digital worksheet and demonstrated that this digital worksheet has the potential to support students' mathematical thinking skills. Furthermore, Istihapsari & Kusuma (2026) integrated interactive student worksheets and Virtual Reality into mathematics learning using a deep learning approach that encourages students to be active, collaborate, reflect, and learn independently.

However, these studies have not specifically integrated Digital Worksheets and Virtual Reality into trigonometry learning to analyze mathematical thinking skills based on four indicators: specializing, generalizing, conjecturing, and convincing. The research gap lies in the absence of a study that specifically describes students' mathematical thinking skills in trigonometry learning using Digital Worksheets assisted by Virtual Reality. Thus, this study aims to describe and analyze students' mathematical thinking skills in trigonometry learning through Digital Worksheet assisted by Virtual Reality. Based on this objective, the research question formulated for this study is: What are students' mathematical thinking skills in trigonometry learning through Digital Worksheets assisted by Virtual Reality?

Method

Research Method

This study employed a qualitative descriptive method to describe and analyze students' mathematical thinking skills in trigonometry learning using a Digital Worksheets assisted by Virtual Reality. This method was used to provide an overview of students' mathematical thinking skills based on their performance on the Digital Worksheets assisted by Virtual Reality, written tests, and interviews.

Participants

The research subjects consisted of 32 tenth-grade students at Belitang 1 Public High School. All students participated in trigonometry lessons using a Digital Worksheets assisted

by Virtual Reality, took a written test, and three students were selected to represent each indicator of mathematical thinking skills.

Instruments

The instruments used in this study included a Digital Worksheets assisted by Virtual Reality, a written test, and interviews. The Digital Worksheets assisted by Virtual Reality was designed for use in trigonometry learning and included activities based on indicators of mathematical thinking skills.

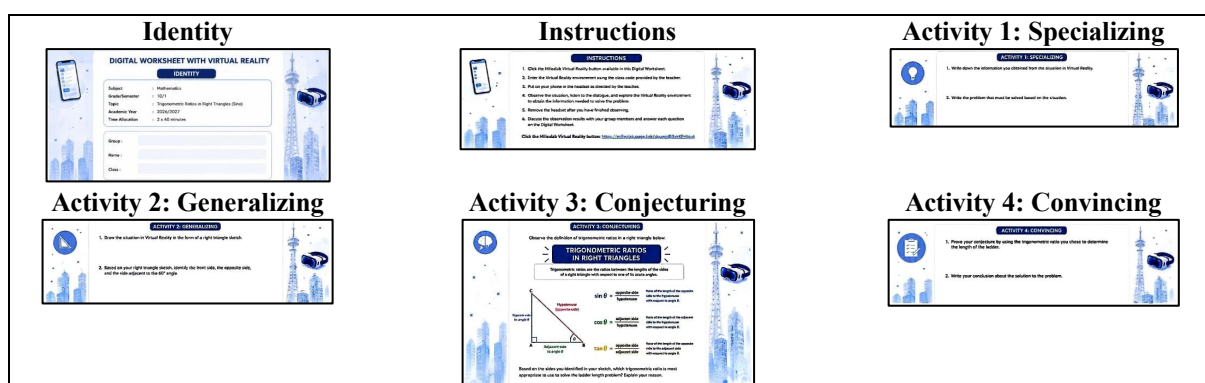


Figure 1. Digital Worksheet assisted by Virtual Reality

The written test in this study consisted of five essay questions. The test was used to identify students' mathematical thinking skills. In addition, interviews were used as a tool to gather information regarding students' mathematical thinking skills based on their responses to the written test.

Research Procedure

The research procedure consists of three stages: the preparation stage, the implementation stage, and the final stage. During the preparation stage, the researcher conducted a literature review and developed and validated the research instruments. During the implementation stage, the researcher conducted trigonometry lessons using a Digital Worksheets assisted by Virtual Reality. After the lessons, students took a written test, followed by interviews. During the final stage, all the data collected were analyzed to provide an overview of the students' mathematical thinking skills. The flowchart of the research procedure is presented in Figure 2.

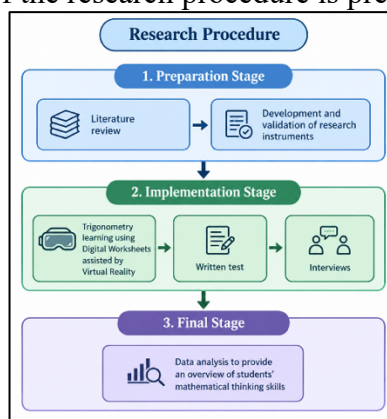


Figure 2. Flowchart of the Research Procedure

Data Collection

Data collection in this study was conducted using a Digital Worksheets assisted by Virtual Reality, written tests, and interviews. Data from the digital worksheet were obtained through student activities during learning. Written test data were obtained from students' answers to five essay questions. Furthermore, interviews were conducted with subjects selected based on their mathematical thinking ability categories.

Data Analysis

Data analysis was conducted using a descriptive qualitative approach through data reduction, data presentation, and drawing conclusions. During the data reduction stage, the researcher grouped data relevant to indicators of mathematical thinking skills. Subsequently, the reduced data were presented descriptively based on students' performance on the Digital Worksheet, written tests, and interviews. Written test scores were assigned based on the presence of indicators of mathematical thinking skills. The scores obtained were then summarized and converted into scores ranging from 0 to 100, and subsequently categorized as high, moderate, or low skills. The categories of mathematical thinking skills are presented in Table 1.

Table 1. Categories of Mathematical Thinking Skills

Score	Category
81-100	Very Good
61-80	Good
41-60	Fair
21-40	Poor
0-20	Very Poor

(Rahman et al., 2026)

These categories were used to identify interview subjects who represented each skills category. In the final stage, the researcher drew conclusions based on the results of the data analysis from the Digital Worksheet, the written test, and the interviews.

Research Findings

Preparation Phase

The first stage is preparation. The results of a study of the Merdeka Curriculum in Phase E indicate that the learning outcome is: "By the end of Phase E, students will be able to solve problems involving right triangles that require trigonometric ratios and their applications." This learning outcome served as the basis for designing a Digital Worksheet assisted by Virtual Reality using contextual trigonometry problems. The content analysis focused on trigonometric ratios in right triangles, which were then used as the basis for determining the learning objectives. Next, the researcher developed and validated the research instruments.

Implementation Phase

The second phase is the implementation phase, in which the researcher conducted trigonometry lessons using Digital Worksheet assisted by Virtual Reality, followed by

administering a test and conducting interviews. The implementation of the trigonometry lessons using Digital Worksheet assisted by Virtual Reality is shown in Figure 3.



Figure 3. Implementation of Learning

Final Stage

In the final stage, all the data collected is analyzed to gain an understanding of the students' mathematical thinking skills.

Digital Worksheet assisted by Virtual Reality

Activity 1: *Specializing*

In Activity 1, students are asked to understand, identify, and analyze a problem by writing down what is known and what is being asked about in the problem.

Group 2	Group 3	Group 5
Diketahui Ada pekerja yang mau memperbaiki jendela lantai 2 yang rusak, pekerja yang kedua bilang kalau tangganya sudah siap, pekerja ke 3 bilang tinggi lantai 1 dan lantai 2 sama yaitu 4 meter, dan ujung tangga tepat berada di di tengah lantai 2, pekerja ke 4 bilang sudutnya berada di 60° terhadap tanah, panjang tangga yang dibutuhkan berapa ya There are several workers who are going to repair a broken window on the second floor. The second worker says that the ladder is ready. The third worker says that the height of the first and second floors is 4 meters each, and the top of the ladder is positioned exactly in the middle of the second floor. The fourth worker says that the ladder forms an angle with the ground. How long should the ladder be?	Tinggi lantai pertama=4 meter Tinggi lantai kedua= 2 meter Sudut tangga=60° Tangga ada pada tengah tengah lantai 2 The information provided: Height of the first floor = 4 meters Height of the second floor = 2 meters Angle of the ladder = 60° The ladder is positioned in the middle of the second floor.	diketahui:tinggi lantai 1 dan 2 masing masing 4 meter sudut tangganya 60° terhadap tanah Given: The height of the first and second floors is 4 m each, and the ladder forms an angle of 60° with the ground.

Figure 4. Activity 1: Specializing Number 1

Figure 4 shows the differences in the skills of Groups 2, 3, and 5 to identify information from a virtual reality scenario. Group 2 tended to copy information without identifying it based on understanding, so the specializing indicator was not fully met. Group 3 was able to identify the information but still incorrectly stated that the height of the second floor was 2 m, so the specializing indicator was not fully met. Meanwhile, Group 5 was able to identify the information accurately: the heights of the first and second floors were 4 m each, and the staircase angle was 60° . Group 5's answers were consistent with those of Groups 1, 4, and 6.

berapa panjang tangga yg di butuhkan?	how tall a ladder is needed?
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Figure 5. Activity 1: Specializing, Number 2

Figure 5 shows that Group 6 was able to identify what was being asked in the problem, namely, determining the length of the ladder needed. Group 6's answer represents all groups, indicating that all groups successfully met the specializing indicator for Number 2.

Activity 2: Generalizing

In Activity 2, students were asked to transform the contextual problem into a right-triangle model based on the situation observed in Virtual Reality.

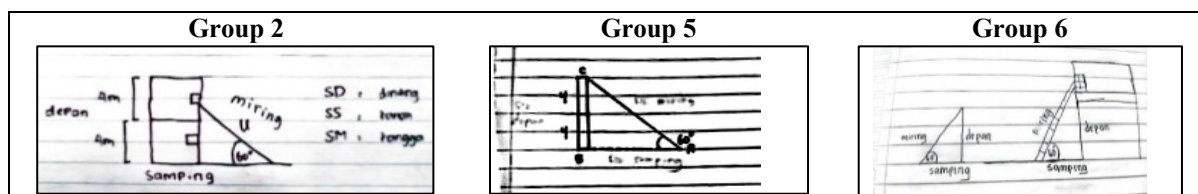


Figure 6. Activity 2: Generalizing

Figure 6 shows the differences in the responses of Groups 2, 5, and 6 in representing a virtual reality situation as a right-angled triangle. Groups 2 and 6 were able to create accurate representations, although they used different drawing methods because they had different perspectives on the virtual reality situation. Group 2's response also reflects those of Groups 1, 3, and 4. Meanwhile, Group 5 still made a mistake by placing the top of the staircase at the very top of the second floor, whereas it should have been in the center of the second floor. Thus, Group 5 demonstrated the generalizing indicator, but not to the fullest extent. In Activity 2, Question 2, all groups were able to identify the front side, the side, and the slanted side at a 60° angle, so all groups met the generalizing indicator well.

Activity 3: Conjecturing

In Activity 3, students are asked to identify the correct trigonometric ratio to determine the length of a staircase based on the relationships between the sides of a right triangle.

Group 3 Menurut saya sin karena perbandingan panjang antara panjang sisi samping (alas) terhadap tetga dengan sisi miring (hipotenusa) I chose sine because it represents the ratio of the opposite side to the hypotenuse.	Group 5 perbandingan trigonometri sin : karena yang ditanya sisi miring diketahui sisi depan maka hubungan yang tepat terkait perbandingan trigonometri adalah SIN For the trigonometric ratio, since the opposite side is known, the appropriate trigonometric ratio is sine.
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Figure 7. Activity 3: Conjecturing

Figure 7 shows that Groups 3 and 5 were able to make conjectures about the sine ratio, although for different reasons. Group 3 identified the sine ratio incorrectly, while Group 5 correctly determined it based on the given and asked sides. Thus, Group 3 partially met the conjecturing indicator, whereas Group 5 met it well. Group 5's answer represents Groups 1, 2, 4, and 6.

Activity 4: Convincing

In Activity 4, students are asked to prove their hypothesis by completing the calculations using the selected trigonometric ratios and writing down their conclusions.

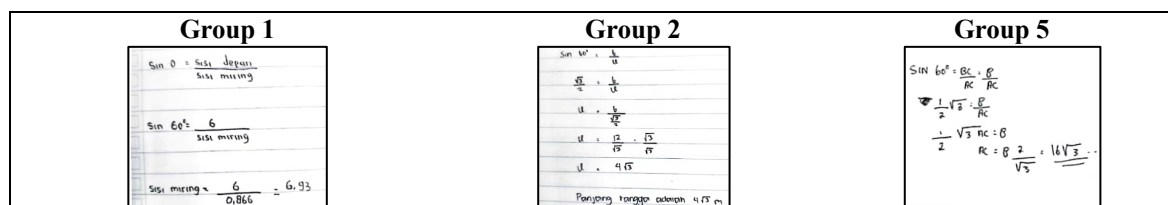


Figure 8. Activity 4: Convincing Number 1

Figure 8 shows that Groups 1 and 2 were able to prove their hypothesis using the sine rule by determining the front side to be 6 m and performing the calculations accurately. The difference lies in the use of the value of $\sin 60^\circ$. Group 1's answer represents Groups 4 and 6, while Group 2's answer represents Group 3. Meanwhile, Group 5 still incorrectly determined the front side to be 8 m, so their calculation process and results were inaccurate. Thus, Groups 1 and 2 met the convincing indicator well, while Group 5 did not perform optimally.

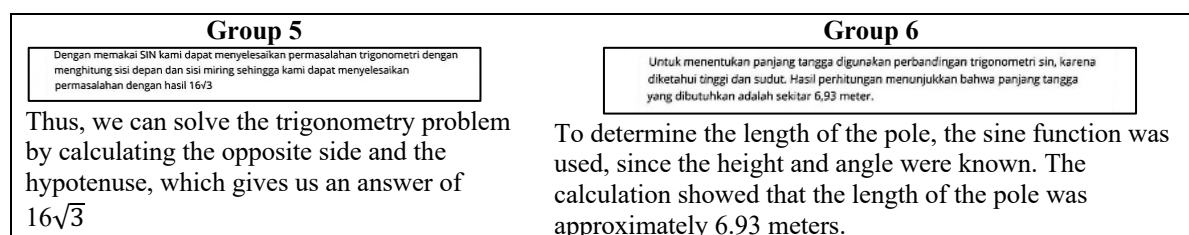


Figure 9. Activity 4: Convincing Number 2

Figure 9 shows that Groups 5 and 6 have written their conclusions. Group 5 concluded that the length of the ladder was determined using the sine ratio, but the result was still inaccurate due to an error in identifying the window height as the front side. Therefore, the convincing indicator was demonstrated, but not to the fullest extent. Meanwhile, Group 6 concluded that the sine ratio was used because the height and angle were known, resulting in a staircase length of 6.93 m. This indicates that Group 6 has met the convincing indicator for item 2. Group 6's answer represents Groups 1, 2, 3, and 4. Overall, the results of the Digital Worksheet assisted by Virtual Reality show that students demonstrated all four indicators of mathematical thinking skills: specializing, generalizing, conjecturing, and convincing. However, the level of achievement for each indicator varied among the groups.

Written Test

The results of the written test show that students' mathematical thinking skills fall into three categories: very good, good, and fairly good. The students' responses in these categories are represented by ADF, HA, and TSR.

The Students' Mathematical Thinking Skills are Very Good

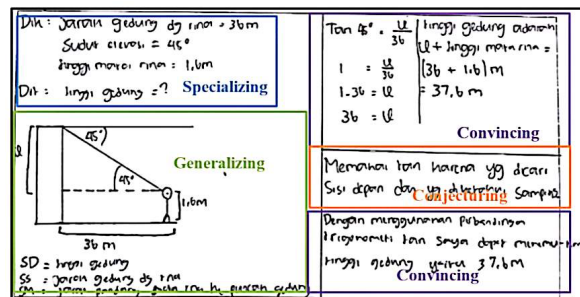


Figure 10. ADF Answer Number 1

Based on ADF's answer to number 1, it is evident that ADF meets the specializing indicator by identifying the known and asked-for information. ADF meets the generalizing indicator by transforming the contextual situation into a right-angled triangle model. ADF meets the conjecturing indicator by estimating the tangent ratio, since the front side is unknown and the side is known. ADF also meets the convincing indicator by proving the result obtained using the tangent trigonometric ratio, then adding the observer's height and concluding that the building's actual height is 37,6 m.

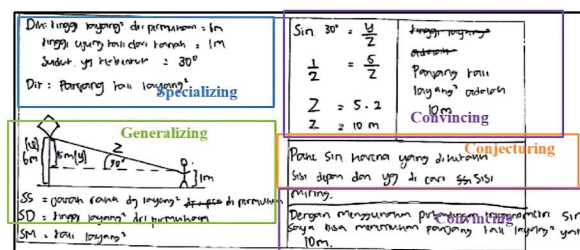


Figure 11. ADF Answer Number 2

Based on ADF's answer to number 2, it is evident that ADF meets the specializing indicator by identifying the known and asked-for information. ADF meets the generalizing indicator by transforming the contextual situation into a right-angled triangle model. ADF meets the conjecturing indicator because ADF hypothesizes the sine ratio to solve the problem, given that the opposite side is known and the hypotenuse is sought. ADF also meets the convincing indicator by proving the results obtained and providing an accurate conclusion.

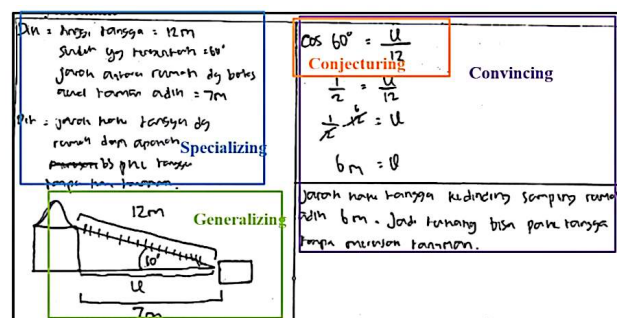


Figure 12. ADF Answer Number 3

Based on ADF's answer to number 3, it is evident that the ADF meets the specializing indicator by identifying known and asked-for information. The ADF meets the generalizing

indicator by transforming the contextual situation into a right-angled triangle model. ADF meets the conjecturing indicator because it hypothesizes a cosine ratio. ADF meets the convincing indicator by performing calculations using the cosine ratio to determine a distance of 6 m and concluding that the ladder can be used without damaging the garden.

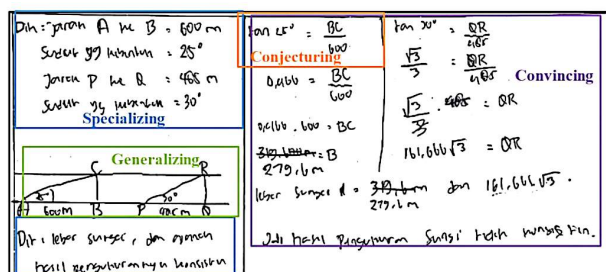


Figure 13. ADF Answer Number 4

Based on ADF's answer to number 4, it is evident that the ADF meets the specializing indicator by identifying known and asked-for information. The ADF meets the generalizing indicator by transforming the contextual situation into a model or illustration of a right triangle. ADF meets the conjecturing indicator because it estimates the tangent ratio. ADF meets the convincing indicator by completing the calculation using the tangent ratio for both measurements, thereby demonstrating that the results obtained are consistent.

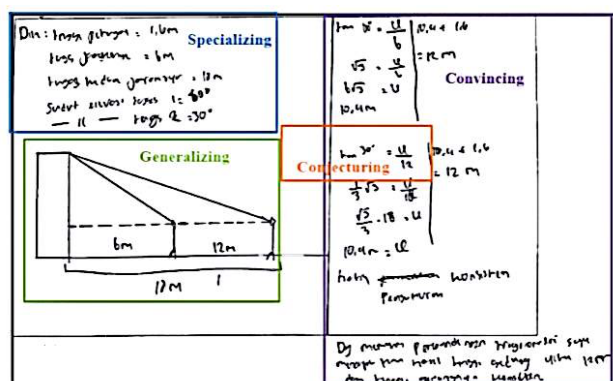


Figure 14. ADF Answer Number 5

Based on ADF's answer to number 5, it is evident that the ADF meets the specializing indicator by identifying known and asked-for information. The ADF meets the generalizing indicator by transforming the contextual situation into a model or illustration of a right triangle. ADF meets the conjecturing indicator because it estimates the tangent ratio. ADF meets the convincing indicator by performing calculations using the tangent trigonometric ratio for both measurements, then adding the observer's height and concluding that the results are consistent.

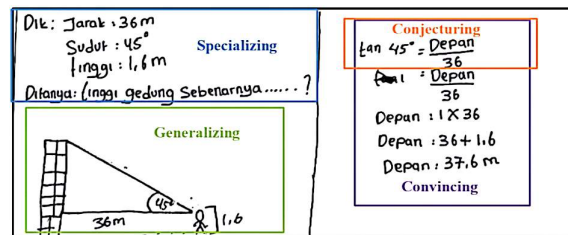


Figure 15. HA Answer Number 1

Based on HA's answer to number 1, it is evident that HA met the specializing indicator by identifying known information and the information being asked for. HA met the generalizing indicator by transforming the contextual situation into a right-angled triangle model. HA meets the conjecturing indicator by hypothesizing a ratio of tangents that can be used to solve the problem. HA meets the convincing indicator, though not to the fullest extent, because HA immediately adds 36 m and 1,6 m as the front side, whereas the front side is actually 36 m.

Interview

- R : Why did you write 37,6 as the front side?
 HA : I thought the front side was the actual height of the building because I had already added 1,6 m.
 R : Why didn't you write the conclusion?
 HA : I was in a hurry, but I know that the conclusion is that the building is 36,7 m tall.

Based on the interview results, regarding the convincing indicator, HA explained that he determined the front side using the tangent ratio, but still mistakenly assumed that result to be the actual height of the building. Although HA was aware of his conclusion, his calculation was still inaccurate. Thus, the convincing indicator has been met, but not to the fullest extent.

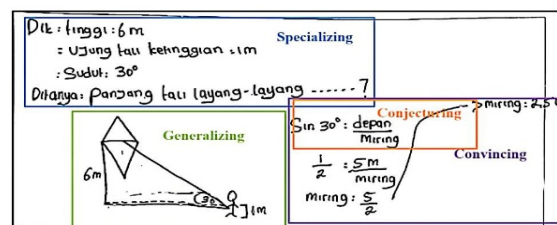


Figure 16. HA Answer Number 2

Based on HA's answer to number 2, it is evident that HA meets the specializing indicator by identifying known and asked-for information. HA meets the generalizing indicator by transforming the contextual situation into a right-angled triangle model, but the drawing still contains a slight error. The conjecturing indicator is evident in HA's answer, which states the ratio of the sine the front side divided by the hypotenuse. HA meets the convincing indicator, but not to the fullest extent, as the calculations are not entirely accurate and are not accompanied by a conclusion.

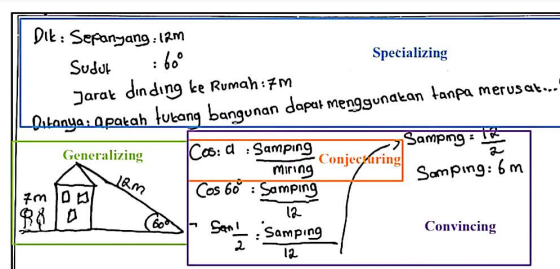


Figure 17. HA Answer Number 3

Based on HA's answer to number 3, HA meets the specializing indicator by identifying known and asked-for information, though the answer is still incomplete. HA meets the generalizing indicator but not to the fullest extent, as there are still errors in HA's illustration. Regarding conjecturing, HA is able to determine the cosine ratio, which is the adjacent side divided by the hypotenuse. For convincing, HA calculated a distance of 6 m but did not compare it to the 7 m distance and did not draw a conclusion; therefore, the convincing indicator is met but not to the fullest extent.

Interview

- R : What exactly was the question asking? Why did you only mention one of them?
- HA : The distance between the base of the ladder and the side wall of the house, and whether the construction worker can use that ladder. I knew that's what the question was asking, but I was in a hurry and only had time to write down one of them.
- R : Why didn't you write down the conclusion?
- HA : I was in a hurry, but I know that the conclusion is that the distance between the base of the ladder and the side wall of the house is 6 meters, and the construction worker can use the ladder.

Based on the interview results, regarding the specializing indicator, HA explained that he actually knew the question was about the distance between the ladder's base and the side wall of the house, as well as whether the construction worker could use the ladder, but HA was in a hurry and therefore wrote down only one of them. Regarding the convincing indicator, HA explained that he knew the results and conclusions namely, that the distance from the base of the ladder to the wall was 6 m and that the construction worker could use the ladder. Thus, the interview results show that HA met the specializing and convincing indicators, even though neither was explicitly stated in his answer.

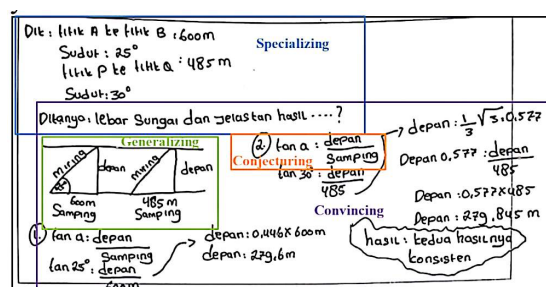


Figure 18. HA Answer Number 4

Based on HA's answer to number 4, HA met the specializing indicator by identifying the given information and the information being asked for. HA met the generalizing indicator by transforming the situation in the problem into a right-angled triangle and determining its sides. For the conjecturing indicator, HA was able to determine the tangent ratio, which is the front

side divided by the side. For the convincing indicator, HA performed calculations for both measurements and concluded that the two results were consistent, thus meeting the convincing indicator.

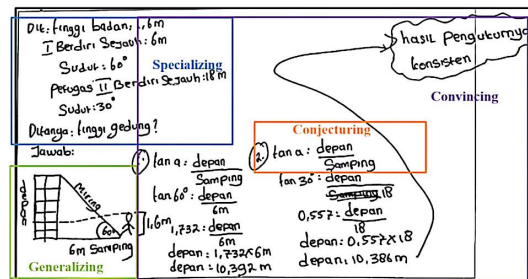


Figure 19. HA Answer Number 1

Based on HA's answer to number 5, HA met the specializing indicator but not to the fullest extent, as the response was still incomplete in identifying the given information and the information being asked for. The generalizing indicator was met but not to the fullest extent, as there were still errors in the illustration HA created. For the conjecturing indicator, HA was able to estimate the ratio of tangents and write down the formula used correctly. For the convincing indicator, HA performed calculations for both measurements and obtained consistent results, but did not include the observer's eye height; thus, the convincing indicator has been met but not to the fullest extent.

Interview

- R : What exactly was the question asking? Why did you only mention one of them?
- HA : The actual height of the building, and whether the results of the two measurements were consistent. I knew that's what the question was asking, but I was in a hurry and only had time to write down one of them.
- R : Why did you only draw a diagram for one of the measurements?
- HA : I only drew a diagram for one of the measurements because I was in a hurry.
- R : Why didn't you add the observer's eye level to determine the actual height, and then conclude that the results were consistent?
- HA : I jumped to a conclusion but didn't add the observer's eye level because I wasn't thorough enough.

Based on the interview results, regarding the specializing indicator, HA actually knew the information being asked namely, the building's actual height and the consistency of the two measurement results but wrote down only one of them because he was in a hurry. Regarding the generalizing indicator, HA explained that he created only one illustration because he was in a hurry. For the convincing indicator, HA immediately drew a conclusion but failed to include the observer's eye level due to a lack of attention to detail. Thus, HA met the specializing indicator well, even though it was not explicitly stated in the answer. However, the generalizing and convincing indicators were met but not to the fullest extent.

The Students' Mathematical Thinking Skills are Fairly Good

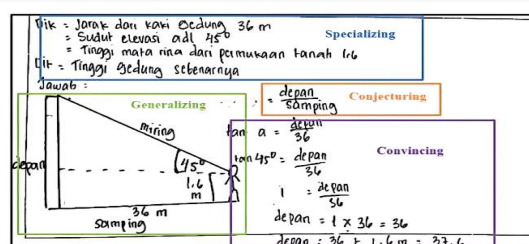


Figure 20. TSR Answer Number 1

Based on TSR's answer to number 1, it is evident that TSR met the specializing indicator by identifying the given information and the information being asked for. TSR met the generalizing indicator by transforming the contextual situation into a right-angled triangle model. TSR meets the conjecturing indicator by hypothesizing a tangent ratio that can be used to solve the problem. TSR meets the convincing indicator, though not to the fullest extent, because TSR immediately adds 36 m and 1,6 m as the front side, whereas the front side is actually 36 m.

Interview

- Interviewer : Why did you just add 1,6 m as the front side?
TSR : I thought the front side was the actual height of the building because I had already added 1,6 m.
R : Why didn't you write a conclusion?
TSR : Because I'm still confused about how to write a conclusion.

Based on the interview results, regarding the convincing indicator, TSR explained that he considered the front side to be the building's actual height because he had added 1,6 m for the eye level, so there was still an error in determining the building's actual height. TSR also did not write a conclusion because he was still unsure how to formulate one. Thus, the convincing indicator has not yet been fully met.

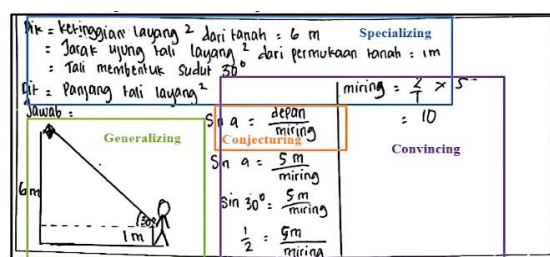


Figure 21. TSR Answer Number 2

Based on TSR's answer to number 2, TSR met the specializing indicator by identifying the given information and the question being asked. For generalizing, TSR was able to draw a model of a right triangle, but there were still some minor errors in the illustration. For conjecturing, TSR was able to determine the sine ratio, which is the opposite side divided by the hypotenuse. In the convincing category, TSR performed the calculations correctly but did not write down the conclusion, so this criterion was not fully met.

Interview

- R : Why didn't you write a conclusion?
TSR : Because I'm still confused about how to write a conclusion.

Based on the interview results, regarding the convincing indicator, TSR explained that he did not include a conclusion because he was still unsure about how to formulate one. This indicates that the convincing indicator has not been fully met.

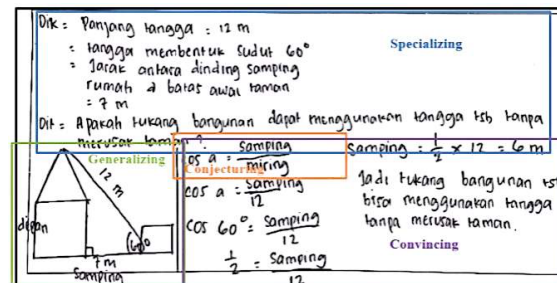


Figure 22. TSR Answer Number 3

Based on the TSR's answer to number 3, the specializing indicator was met, but not to the fullest extent because the information provided was incomplete. The generalizing indicator was also not fully met, as the illustration provided was not entirely accurate. Regarding conjecturing, the TSR was able to accurately determine the ratio of the cosines. Regarding convincing, the TSR performed the calculations correctly, determined the distance to be 6 m, and drew the correct conclusion.

Interview

- R : What exactly was the question asking? Why did you only mention one of them?
- TSR : The distance between the ladder's feet and the side wall of the house, and whether the construction worker could use that ladder. I knew that's what the question was asking, but I was in a hurry and only had time to write down one of them.
- R : What exactly was the question asking? Why did you only mention one of them?
- TSR : The distance between the ladder's feet and the side wall of the house, and whether the construction worker could use that ladder. I knew that's what the question was asking, but I was in a hurry and only had time to write down one of them.

Based on the interview results, regarding the specializing indicator, TSR explained that he actually knew the question was about the distance between the ladder's feet and the side wall of the house and whether a construction worker could use that ladder, but because he was in a hurry, TSR wrote down only one of them.

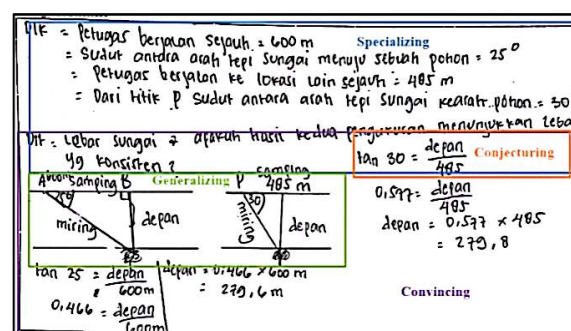


Figure 23. TSR Answer Number 4

Based on TSR's answer to question number 4, TSR met the specializing indicator by writing down the known information and the information being asked for. For generalizing,

TSR was able to transform the situation into a right-angled triangle model and determine its sides. For conjecturing, TSR hypothesized the trigonometric ratio of the tangent used to solve the problem. For convincing, TSR performed calculations for both measurements but did not state a conclusion regarding whether the results were consistent; thus, the conjecturing indicator was not met, and while the convincing indicator was met, it was not fully met.

Interview

- R : Why didn't you write a conclusion?
 TSR : Because I'm still confused about how to write a conclusion.

Based on the interview results, regarding the convincing indicator, TSR explained that he did not include a conclusion because he was still unsure about how to formulate one. This indicates that the convincing indicator has not been fully met.

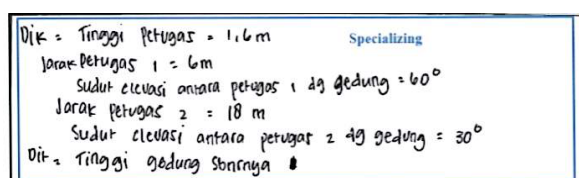


Figure 24. TSR Answer Number 5

Based on answer number 5, TSR meets the specializing indicator by providing complete information regarding both known facts and the questions asked. However, regarding the generalizing, conjecturing, and convincing indicators, TSR has not demonstrated a problem-solving process; therefore, these three indicators have not been met.

Interview

- R : Why didn't you finish the problem?
 TSR : I ran out of time.

Based on the interview results, TSR explained that he did not complete question number 5 because he ran out of time. This indicates that TSR did not have the opportunity to demonstrate the problem-solving process for the indicators of generalizing, conjecturing, and convincing; therefore, these three indicators have not been met.

Discussion

Overall Achievement of The Mathematical Thinking Skills Indicators

The research results show that, overall, students have demonstrated all four indicators of mathematical thinking skills: specializing, generalizing, conjecturing, and convincing. These four indicators were evident in the students' process of identifying known and unknown information, transforming situations into right-angle triangle representations, making conjectures about trigonometric ratios, and testing those conjectures through calculations to draw conclusions. However, the level of achievement across these four indicators still varied among the different student groups. These findings indicate that mathematical thinking is not merely about arriving at a final answer, but involves a series of interconnected processes from understanding information, constructing representations, and making conjectures, to justifying the results obtained. Differences in achievement levels across groups also suggest that mastery of one indicator does not necessarily imply mastery of others.

Analysis of Mathematical Thinking Indicators

In specializing indicator, most groups were able to identify known and requested information, although some still copied information or inaccurately determined the height of the second floor. [Lorenza et al. \(2024\)](#) and [Jamiludin et al. \(2025\)](#) explain that specializing involves understanding problems and selecting important information. During the process, students first access the Virtual Reality link provided in the Digital Worksheet and observe the problem scenario presented. Their observations of the Virtual Reality scenario help students understand the context before identifying the given and unknown information. Thus, Virtual Reality visualizes abstract trigonometric concepts, while the Digital Worksheet guides students in identifying the information needed to solve the problem.

In generalizing, most groups were able to represent the Virtual Reality situation as a right triangle, although some still made errors in their representations. [Jamiludin et al. \(2025\)](#) state that these errors stem from students' difficulty in generalizing abstract concepts. [Sugianto et al. \(2024\)](#) and [Hunter & Miller \(2022\)](#) state that generalizing involves visualization, representation, and the formation of mathematical relationships. This is also supported by [Susanti et al. \(2024\)](#), who state that generalizing is evident when students are able to identify patterns. In this process, Virtual Reality helped students visualize the positions of the ladder, building, and ground surface, making it easier for them to represent the situation as a right triangle.

In conjecturing, most groups were able to estimate sine ratios based on the relationships between known and unknown sides, although some still made errors. According to [Nuha & Panlaan \(2026\)](#), these errors occurred because students still struggled to make predictions based on mathematical conjecture patterns. [Sutarto et al. \(2022\)](#) explain that conjecturing involves observing patterns and making conjectures. Some groups required teacher scaffolding to refine their conjectures, as described by [DeJarnette & Hord \(2022\)](#) and [Vroom & Ellis \(2024\)](#). In this process, the Digital Worksheet assisted by Virtual Reality provided the definition of trigonometric ratios in right triangles, helping students make conjectures about the appropriate trigonometric ratio based on the relationships between the known and unknown sides.

In convincing, most groups were able to prove their conjectures through sine calculations, although some still incorrectly identified the front side, which affected the results and conclusions. This convincing stage involves identifying and communicating the reasons why something is correct ([Delima et al., 2021](#)). However, some groups still struggled with both calculations and drawing conclusions; this was because students had difficulty connecting ideas and explaining the final results they obtained ([Amalia & Murtiyasa et al., 2023](#)). In this process, the Digital Worksheet assisted by Virtual Reality guided students to test their conjectures through calculations and draw conclusions based on the results obtained.

Differences in Mathematical Thinking Skills Among Students with Very Good, Good, and Fairly Good

Based on the results of the written test, students' mathematical thinking skills fell into the categories of very good, good, and fairly good. Students with very good skills, represented by ADF, were able to demonstrate all four indicators: specializing, generalizing, conjecturing, and convincing. ADF was able to fully identify the given information and the information requested in the problem, accurately represent the problem as a right triangle, conjecture the appropriate trigonometric ratios to solve the problem, and perform calculations to arrive at the correct

conclusion. According to [Hanifah et al. \(2026\)](#), students with very strong mathematical thinking skills are able to demonstrate all indicators of mathematical thinking. This is also consistent with [Rahman et al. \(2026\)](#), who state that students with very strong skills are able to clearly demonstrate all indicators of mathematical thinking.

Based on the results of the written test and interview, HA was able to meet all four indicators of mathematical thinking specializing, generalizing, conjecturing, and convincing across all five problems. For some problems, the indicators were met but not to the fullest extent, as there were still errors in representing the problem situations as right triangles, in the calculations, and in the conclusions. The interview results also showed that some shortcomings in the written answers were caused by rushing and a lack of attention to detail, even though HA actually understood the information, solution strategies, and necessary conclusions. These findings are consistent with [Mansor et al. \(2021\)](#), who explained that students' errors in solving math problems do not always indicate a lack of mathematical skills but can be caused by a lack of attention to detail in the problem-solving process.

Students with fairly good skills, as represented by TSR, were able to demonstrate indicators of specializing, but were not yet able to consistently meet all indicators of generalizing, conjecturing, and convincing. In specializing, TSR was able to identify known and requested information by reading the questions, although in some questions the information provided was still incomplete. In the generalizing, TSR students are able to transform contextual problems into right-triangle models, but errors still occur in creating these representations. This finding aligns with [Çakıroğlu & Muştuoğlu \(2025\)](#), who found that students can make generalizations even if they are incomplete or incorrect. According to [Wardhani & Argaswari \(2022\)](#), students' difficulties in generalizing may be related to a lack of ability to transform information in word problems into appropriate mathematical models and strategies. In the conjecturing phase, TSR students were able to conjecture trigonometric ratios in some problems, but in certain problems, they did not provide their conjectures in writing. In the convincing phase, TSR students were able to perform calculations in some problems but still struggled to draw conclusions. [Amalia & Murtiyasa \(2023\)](#) found that students still frequently experience difficulties in the conjecturing and convincing processes because they are not yet fully able to connect ideas obtained from similar cases and provide explanations for the final results of their solutions.

Implications of the Research Findings

The results of the study show that teaching trigonometry using Digital Worksheet assisted by Virtual Reality can enhance students' mathematical thinking skills. Digital Worksheets provide structured guidance to help students identify relevant information, represent contextual problems as right triangles, make conjectures, and prove the proposed solutions. Meanwhile, Virtual Reality provides a visual context that helps students observe and explore objects in trigonometric situations. The integration of these two technologies gives students the opportunity to connect visual experiences with mathematical thinking processes. These findings indicate that Digital Worksheet assisted by Virtual Reality can serve as an alternative learning resource in trigonometry learning. Teachers can use Virtual Reality to provide visual experiences at the beginning of a lesson, then guide students through Digital Worksheets containing structured activities that include specializing, generalizing, conjecturing, and convincing. This approach can provide students with opportunities to actively engage in mathematical thinking. In practice, teachers need to consider students' readiness and the

availability of technological resources so that the use of Digital Worksheet assisted by Virtual Reality can optimally support the mathematical thinking process in trigonometry learning.

Conclusion

The results of this study indicate that the use of Digital Worksheet assisted by Virtual Reality can support students' mathematical thinking skills in trigonometry learning. Digital worksheets provide a structured activity that guides students to identify information, construct representations, make conjectures, and test those conjectures through mathematical problem-solving. Virtual Reality then provides a visual context that helps students understand and represent trigonometric situations within these activities. These findings suggest that the integration of digital worksheets and Virtual Reality can connect contextual situations with students' mathematical thinking processes. The results of this study indicate that Digital Worksheet assisted by Virtual Reality in trigonometry learning to support students' mathematical thinking skills. Based on the results of the written test, there were differences in students' mathematical thinking abilities across the categories of very good, good, and fairly good. Students with very good abilities were able to demonstrate all four indicators specializing, generalizing, conjecturing, and convincing completely and accurately. Students with good abilities were also able to demonstrate these four indicators, but some errors and inaccuracies were still found in their problem-solving processes. Meanwhile, students with fairly good abilities were more consistent in demonstrating the specializing indicator but still experienced difficulties in meeting the generalizing, conjecturing, and convincing indicators. The causes of these difficulties stem from limitations in translating information into mathematical models, connecting ideas to similar cases, and explaining the results of the solutions. This study is limited to the teaching of trigonometric ratios in right triangles using a Digital Worksheet assisted by Virtual Reality. Its implementation requires adequate hardware and internet connectivity, specifically a smartphone compatible with Virtual Reality technology and a stable internet connection. Therefore, the use of a Digital Worksheet assisted by Virtual Reality is more suitable for students and schools that have the necessary technological infrastructure. Future research could explore the use of Digital Worksheet assisted by Virtual Reality in other mathematics topics to examine their application in a broader learning context.

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Declarations

- Conflict of Interest** : The authors declare that there are no conflicts of interest.
- Auhor Contributions** : N.N.: Methodology, Investigation, Formal analysis, Writing – original draft.
E.S.: Supervision, Methodology, Writing – review & editing.
M.: Validation, Formal analysis, Writing – review & editing.
- Data Availability Statement** : Data supporting the findings of this study are available from the author, N.N., upon reasonable request.
- AI Statement** : The authors state that generative AI tools were used solely to improve the clarity, grammar, and readability of the English language in the manuscript. All content, research findings, and data analysis were produced by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the manuscript.

References

- Adhikari, T. N., & Subedi, A. (2021). Difficulties of grade x students in learning trigonometry. *Siddhajyoti Interdisciplinary Journal*, 2(01), 90–99. <https://doi.org/10.3126/sij.v2i01.39243>
- Adnan, M., Tek, W. W., Adenan, N. H., Bahurudin, M. A., Setambah, & Rusdin, N. M. (2024). Mathematical Thinking Among Pre-Service Teachers: A Critical Component of Teacher Preparation. *Journal of Electrical Systems*, 20(4s), 1584–1594. <https://doi.org/10.52783/jes.2218>
- Afifah, N., Rachman, P., & Zairozie, A. Z. (2026). Enhancing students' mathematical thinking skills through canva-based project-based learning. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, 6(2), 681–697. <https://doi.org/10.51574/kognitif.v6i2.4944>
- AlAli, R., Wardat, Y., & Al-Qahtani, M. (2023). SWOM Strategy and Influence of Its Using on Developing Mathematical Thinking Skills and on Metacognitive Thinking Among Gifted Tenth-Grade Students. *EURASIA Journal of Mathematics, Science and Technology Education*, 19(3), em2238. <https://doi.org/10.29333/ejmste/12994>
- Amalia, N. R., & Murtiyasa, B. (2023). Analisis kemampuan berpikir matematis siswa berdasarkan taksonomi bloom dalam menyelesaikan soal relasi dan fungsi. *HISTOGRAM: Jurnal Pendidikan Matematika*, 7(1), 427–441. <https://doi.org/10.31100/histogram.v7i1.2606>
- Assidiqi, H., & Sugiman, S. (2026). Augmented and virtual reality for abstract mathematical visualization: A systematic review of cognitive outcomes. *Mathline : Jurnal Matematika dan Pendidikan Matematika*, 11(3), 651–666. <https://doi.org/10.31943/mathline.v11i3.1154>
- Audina, C. P., Susanti, E., & Aisyah, N. (2025). Development of inquiry-based digital worksheet to improve mathematical thinking ability. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 14(2), 570–586. <https://doi.org/10.24127/ajpm.v14i2.10811>
- Basir, M. A., Agustyani, M., & Maharani, H. R. (2024). Innovative trigonometry learning: The role of liveworksheets-assisted interactive worksheets in improving numerical literacy: innovative trigonometry learning. *Mosharafa: Jurnal Pendidikan Matematika*, 13(3), 605–620. <https://doi.org/10.31980/mosharafa.v13i3.2366>

- Çakıroğlu, Ü., & Muştuoğlu, E. (2025). Mathematical thinking behind coding: Promoting generalization skills via scratch. *International Journal of Science and Mathematics Education*, 23(7), 2375–2396. <https://doi.org/10.1007/s10763-025-10556-9>
- Chen, T. L., Lee, Y. C., & Hung, C. S. (2022). A Study on The Effects of Digital Learning Sheet Design Strategy on The Learning Motivation and Learning Outcomes of Museum Exhibition Visitors. *Education Sciences*, 12(2), 135. <https://doi.org/10.3390/educsci12020135>
- DeJarnette, A. F., & Hord, C. (2022). Mathematics questioning practices of pre-service special education teachers providing algebra tutoring for students with learning disabilities. *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, 45(4), 309–330. <https://doi.org/10.1177/08884064211073573>
- Delima, N., Kusumah, Y. S., & Fatimah, S. (2021). Capaian kemampuan mathematical thinking siswa melalui model comprehensive mathematics instructions. *Jurnal Elemen*, 7(1), 146–163. <https://doi.org/10.29408/jel.v7i1.2793>
- Fauzi, N. I., Sagita, L., Setiyani, & Wicaksono, B. (2022). Analysis of student errors in solving trigonometry problems based on the newman procedure. *Kalamatika: Jurnal Pendidikan Matematika*, 7(1), 1–14. <https://doi.org/10.22236/KALAMATIKA.vol7no1.2022pp1-14>
- Ferdianto, F., Sukestiyarno, Y. L., Widowati, & Junaedi, I. (2025). Analysis mathematical thinking skills in three-dimensional shapes using the study saster modle. *Pakistan Journal of Life and Social Sciences (PJLSS)*, 23(1). <https://doi.org/10.57239/PJLSS-2025-23.1.00460>
- Hanifah, Lestari, W.D., Roesdiana, L., & Hidayati, N. (2026) Kemampuan Berpikir Matematis Siswa Berdasarkan Teori Mason. *Teorema: Teori dan Riset Matematika*, 11(1), 9–20. <https://dx.doi.org/10.25157/teorema.v10i1.21334>.
- Hidayat, W., Rohaeti, E. E., Hamidah, I., & Putri, R. I. I. (2023). How can android-based trigonometry learning improve the math learning process? *Frontiers in Education*, 7, 1101161. <https://doi.org/10.3389/feduc.2022.1101161>
- Hunter, J., & Miller, J. (2022). The use of cultural contexts for patterning tasks: Supporting young diverse students to identify structures and generalise. *ZDM – Mathematics Education*, 54(6), 1349–1362. <https://doi.org/10.1007/s11858-022-01386-y>
- Ibrahim, H., Tunku Ahmad, T. B., & Isa, N. (2023, December). Exploring Malaysian Students' Mathematical Thinking Skills. In *Forum Paedagogik* (Vol. 14, No. 2, pp. 187-209). <https://doi.org/10.24952/paedagogik.v14i2.9518>
- Istihapsari, V., & Kusuma, J. W. (2026). Transformation of junior high school mathematics learning: Integration of interactive student worksheet and virtual reality based on deep learning approach. *JTAM (Jurnal Teori dan Aplikasi Matematika)*, 10(1), 109. <https://doi.org/10.31764/jtam.v10i1.33737>
- Jamiludin, Moh. F., Suwito, A., Susanto, & Frenza. (2025). Analysis of students specializing and generalizing thinking in three-dimensional geometry. *Jurnal Pendidikan Matematika (JPM)*, 11(1), 107–116. <https://doi.org/10.33474/jpm.v11i1.23346>
- Jawad, L. F., Majeed, B. H., & ALRikabi, H. T. S. (2021). The Impact of CATs on Mathematical Thinking and Logical Thinking Among Fourth-Class Scientific Students. *International Journal of Emerging Technologies in Learning*, 16(10), 194–211. <https://doi.org/10.3991/ijet.v16i10.22515>
- Lara-Alvarez, C. A., Parra-González, E. F., Ortiz-Esparza, M. A., & Cardona-Reyes, H. (2023). Effectiveness of Virtual Reality in Elementary School: A Meta-Analysis of Controlled

- Studies. *Contemporary Educational Technology*, 15(4), ep459. <https://doi.org/10.30935/cedtech/13569>
- Lestari, A. O., Susanti, E., & Hartono, Y. (2022). Pengembangan Digital Worksheet pada Materi Transformasi Geometri untuk Melatih Kemampuan Berpikir Matematis. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 11(4), 2915-2928. <https://doi.org/10.24127/ajpm.v11i4.6160>
- Lorenza, N., Sudirman, S., & Susiswo, S. (2024). Students' specializing thinking in solving arithmetic sequence and series problems. *PRISMA*, 13(1), 70. <https://doi.org/10.35194/jp.v13i1.3930>
- Madadina, Z. R., Hadiprasetyo, K., & Hadianito, U. (2024). Penerapan problem based learning melalui pendekatan tutor sebaya dalam meningkatkan prestasi belajar matematika pada materi trigonometri. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, 4(1), 442–455. <https://doi.org/10.51574/kognitif.v4i1.1565>
- Maghfiroh, F., Dasari, D., Dahlan, J. A., Inayah, C. F., & Fitriyah, Y. (2024). Students' ways of understanding and ways of thinking in solving trigonometric problems. *JIPM (Jurnal Ilmiah Pendidikan Matematika)*, 12(2), 310. <https://doi.org/10.25273/jipm.v12i2.18833>
- Mansor, S. N. A., Samsudin, N., & Ahmad Shukri, F. N. (2021). Newman's error analysis of common errors in solving convergence of power series using ratio test. *International Journal of Academic Research in Business and Social Sciences*, 11(9), Pages 888-898. <https://doi.org/10.6007/IJARBS/v11-i9/11077>
- Monteleone, C., Miller, J., & Warren, E. (2023). Conceptualising Critical Mathematical Thinking in Young Students. *Mathematics Education Research Journal*, 35(2), 339-359. <https://doi.org/10.1007/s13394-023-00445-1>
- Nuha, M. 'Azmi, & Panlaan, J. M. R. (2026). Analysis of mathematics students' mathematical thinking based on learning styles. *Union: Jurnal Ilmiah Pendidikan Matematika*, 14(1), 110–127. <https://doi.org/10.30738/union.v14i1.22658>
- Obeng, B. A., Banson, G. M., Owusu, E., & Owusu, R. (2024). Analysis of senior high school students' errors in solving trigonometry. *Cogent Education*, 11(1), 2385119. <https://doi.org/10.1080/2331186X.2024.2385119>
- Oktaviyanthi, R., & Sholahudin, U. (2023). Phet assisted trigonometric worksheet for students' trigonometric adaptive thinking. *Mosharafa: Jurnal Pendidikan Matematika*, 12(2), 229–242. <https://doi.org/10.31980/mosharafa.v12i2.779>
- Orhak, S., & Çağıltay, K. (2024). Unlocking The Potential of Virtual Reality in Education: Insights from Teachers and Recommendations for Integration. *Journal of Educational Technology and Online Learning*, 7(2), 243-253. <https://doi.org/10.31681/jetol.1419279>
- Rahman, M. R., Nurhalita, N., Sindi, S., Hartono, Y., & Darmawijoyo, D. (2026). Junior high school students' mathematical thinking ability on set theory material based on the apos theory. *Edumatica : Jurnal Pendidikan Matematika*, 16(1), 203–217. <https://doi.org/10.22437/edumatica.v16i1.51317>
- Sabanal, R. M., & Guevara, A. A. (2025). Students' Errors in Solving Word Problems Involving Angles of Elevation and Depression and Performance Level in Grade 9 Trigonometry: Basis for Development of A Teacher-Made Material. *International Journal of Latest Technology in Engineering, Management & Applied Science*, 14(3), 216-235. <https://doi.org/10.51583/IJLTEMAS.2025.140300026>
- Satria, D., Zulhiddah, Z., & Zulkifli, N. A. (2025). Developing Digital Worksheet Based on Project Based Learning Model to Enhance Writing Ability of Junior High School

- Student. *Innovative: Journal Of Social Science Research*, 5(1), 1400-1414. <https://doi.org/10.31004/innovative.v5i1.17495>
- Shidqiya, A. I., & Sukestiyarno, S. (2022). Analysis of students' mathematical thinking ability in terms of self efficacy. *Unnes Journal of Mathematics Education*, 11(3), 272–281. <https://doi.org/10.15294/ujme.v11i3.58772>
- Singh, P., Nasir, N. A. M., & Hoon, T. S. (2024). The Cognitive Gap in The Mathematical Thinking Abilities of High School Leavers for College: Are They Ready?. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(11), em2529. <https://doi.org/10.29333/ejmste/15577>
- Singh, P., Teoh, S. H., Nasir, N. A. M., Cheong, T. H., & Rasid, N. M. (2022). An Assessment of High School Leavers' Development of Mathematical Thinking. *Environment-Behaviour Proceedings Journal*, 7(SI8), 3-9. <https://doi.org/10.21834/ebpj.v7iSI8.3907>
- Sugianto, A., Rosjanuardi, R., & Lukman, L. (2024). Strategies and representation employed by primary school students in a functional relationship: A focus on generalization process. *Jurnal Pendidikan MIPA*, 25(4), 2013–2028. <https://doi.org/10.23960/jpmipa/v25i4.pp2013-2028>
- Susanti, E., Delfi, I., Hapizah, H., Indaryanti, I., Isrok'atun, I., & Simarmata, R. H. (2024). Designing number pattern questions to assess students with kinesthetic learning styles' in mathematical thinking. *SJME (Supremum Journal of Mathematics Education)*, 8(1), 13–28. <https://doi.org/10.35706/sjme.v8i1.9998>
- Sutarto, Dwi Hastuti, I., Fuster-Guillén, D., Palacios Garay, J. P., Hernández, R. M., & Namaziandost, E. (2022). The effect of problem-based learning on metacognitive ability in the conjecturing process of junior high school students. *Education Research International*, 2022, 1–10. <https://doi.org/10.1155/2022/2313448>
- Tsaaqib, A., Buchori, A., & Endahwuri, D. (2022). Efektivitas penggunaan media pembelajaran Virtual Reality (VR) pada materi trigonometri terhadap motivasi dan hasil belajar matematika siswa sma. *JIPMat*, 7(1), 11–19. <https://doi.org/10.26877/jipmat.v7i1.9950>
- Utaminingsih, S., Amalia, I., & Sumaji, S. (2024). Management of mathematics learning based on interactive digital worksheets to improve students' critical thinking ability. *Journal of Curriculum and Teaching*, 13(1), 159. <https://doi.org/10.5430/jct.v13n1p159>
- Vroom, K., & Ellis, B. (2024). Sociomathematical scaffolding as students engage in revising draft definitions, conjectures, and proofs. *Educational Studies in Mathematics*, 116(1), 27–47. <https://doi.org/10.1007/s10649-023-10294-1>
- Wardhani, T. A. W., & Argaswari, D. P. A. D. (2022). High school students' error in solving word problem of trigonometry based on newman error hierarchical model. *Infinity Journal*, 11(1), 87. <https://doi.org/10.22460/infinity.v11i1.p87-102>

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