

## DEVELOPMENT OF A TEST INSTRUMENT CONTAINING STEM COMPONENTS TO MEASURE ANALYTICAL THINKING SKILL IN TRIGONOMETRIC RATIOS

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### Abstract

This study focuses on creating assessment tools to evaluate how well students can think analytically about math when dealing with trigonometric comparisons, assessing how accurate, consistent, and challenging each question is. Thirty-one students in the eleventh grade at SMAN 1 Rawamerta took part in this research. The 4D model was the method utilized for development, but it was streamlined to a 3D process (define, design, and develop). The assessment tool that was developed comprised four open-ended questions. Three college instructors and a seasoned teacher, acting as expert evaluators, examined the content, appearance, and structure of the test to ensure it was valid. Following the declaration of validity for the test tool, a small-scale trial was carried out to ascertain its real-world validity, dependability, and degree of difficulty. The expert validation results showed that this tool is highly valid, achieving a validity score of 97.92%. According to the calculations for real-world validity, this test instrument meets the criteria for good validity. The reliability test findings indicate good criteria with a calculated  $r$  value of 0.7241. Regarding difficulty, one question was classified as easy, while three questions were deemed to be of medium difficulty. Consequently, the assessment tool created can be considered suitable for use as a test containing STEM elements for gathering research data to gauge students' mathematical analytical thinking abilities. Furthermore, it is anticipated that educators can utilize this assessment tool as an evaluation material to thoroughly assess students' thinking capabilities at different stages.

**Keywords:** test instruments, analytical thinking skills, STEM

### INTRODUCTION

Education plays an important role in improving the quality of students' abilities. In education, students have two roles, namely as subjects and objects (Ramli, 2015). As subjects, students play an active role in the learning process, building knowledge and developing thinking skills through various learning activities. Meanwhile, as objects, students play a role as recipients of educational services designed to guide, direct, and develop their abilities optimally. These two roles show that the abilities acquired by students are highly dependent on the learning process that has been designed. One of the components for determining success in measuring student abilities is shown in the assessment system. This statement agrees with Ndiung and Jediut (2020), who state that improvements in the quality of education can be seen through the quality of learning and the quality of the assessment system (Ndiung & Jediut, 2020). One of the assessment systems implemented in schools is a

knowledge assessment. Knowledge assessment is an assessment conducted to measure students' abilities (Jeprianto et al., 2021).

One of the most important skills students need to have today is analytical thinking. Analytical thinking is the most fundamental skill that students need to master to master other higher-level skills (Thaneerananon et al., 2016; Wahyuni & Analita, 2017). In analyzing, there is a process of separating problems into important parts, detecting the relationship between one part and another to connect them into a conclusion from the overall information (Anderson & Krathwohl, 2010; Krathwohl, 2002). Furthermore, having analytical thinking skills is also a complex process that can help understand complex problems, make the right decisions, and advance scientific research and innovation (Wang et al., 2025). Analytical thinking skills also play a role in training other skills, such as reasoning, planning, and scientific investigation using knowledge that has been learned to understand natural phenomena (Permana et al., 2019; Saputra et al., 2020). Based on this, it directly directs students towards critical thinking, problem solving, and creativity (Areesophonpichet, 2013). Thus, students who have analytical thinking skills will be better prepared to face various challenges.

The indicators of analytical thinking skills are distinguishing, organizing, and connecting (Krathwohl, 2002). In distinguishing, students can determine and identify relevant information to solve problems. In organizing, students can arrange or explain the relevance of pieces of information to the question and develop strategies for problem-solving. In connecting, students can determine the purpose and relationship or conclude from the information provided. However, the tools for measuring this ability are still limited in their development. This poses a challenge, necessitating further research to create appropriate test instruments to assess analytical thinking skills (Wang et al., 2025). Test instruments are measuring tools used to collect information and data in determining student learning outcomes (Agustiani et al., 2022; Sa'diyyah et al., 2021).

Currently, test instruments in mathematics are still dominated by problems related to natural phenomena. However, in solving these problems, test instruments in mathematics require engineering to model or illustrate the problems into simpler forms, and in many cases, technological tools are also needed to support accuracy in calculations. This is in line with the opinion of Saputra, Herpratiwi, and Caswita (2020), who stated that science, mathematics, technology, and engineering have a role in mathematics learning to solve mathematical

problems (Saputra et al., 2020), especially contextual problems (Prawita et al., 2019). Science describes a phenomenon or concept, technology is a tool used to help solve problems, engineering is a medium for illustrating or modeling a problem that occurs, and mathematics is a tool or way of thinking used to solve problems through calculations based on mathematical concepts. In research, this is known as STEM.

STEM is a four-disciplinary field that encompasses science, technology, engineering, and mathematics. According to Sanders (2009), STEM is a combination of two or more fields of knowledge found in STEM disciplines (Sanders, 2009). Meanwhile, Kelley and Knowles (2016) argue that STEM teaches and combines real-world (contextual) content and context with problem solving (Kelley & Knowles, 2016). Furthermore, this can broaden the concept to be integrated with other subject matter (Saputra et al., 2020). Meanwhile, Torlakson (2014) states that science is considered the study of nature, which includes physics, chemistry, biology, and the application of facts/concepts/conventions related to scientific disciplines, as well as a collection of accumulated knowledge and scientific investigations that will produce new knowledge; technology is the result of knowledge that can be used to create or facilitate solutions; engineering as knowledge in designing and creating man-made products, as well as engineering to facilitate problem solving; mathematics as the study of patterns and relationships between quantities, numbers, and space through logical arguments, as well as activities required in calculations based on mathematical concepts (Torlakson, 2014).

In fact, analytical thinking skills are still relatively rare, especially when combined with STEM and material related to contextual problems that cover components of STEM, one of which is trigonometric comparison material. This is evident from a search using Publish or Perish 8 and VOSviewer with the keywords analytical thinking skills, STEM, mathematics, test instruments, and trigonometry in the 2020-2025 time frame, which shows that there is a correlation between analytical thinking skills and components of STEM, trigonometry and STEM, but there is little or no research related to analytical thinking skills and trigonometry. In fact, no research combines analytical thinking skills, STEM, and trigonometry, as can be seen in Figure 1.

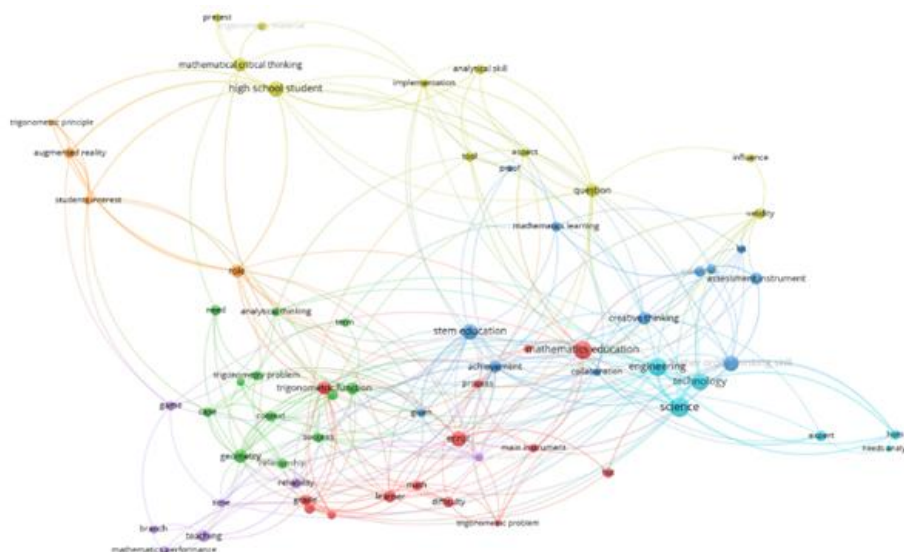


Figure 1. Networking Visualization – Analytical Thinking Skills, STEM, Mathematics, Instrumental test, and Trigonometry

Based on the importance of analytical thinking skills that students need to have as basic skills, existing research is still relatively limited, and there is a correlation between analytical thinking skills, STEM, and trigonometry. Therefore, this research is very necessary and serves as a new development to support further research. The test instrument developed can be used as a tool to measure students' abilities and success.

## METHODS

This study is an instrument development study. The development model used in this study is the 4D model developed by Thiagarajan, Semmel, and Semmel, which has been simplified into three stages (define, design, and develop) (Thiagarajan et al., 1974). The research was conducted in November 2025 at SMA Negeri 1 Rawamerta with a limited test subject group consisting of 31 students in grade XI. The resulting test instrument can be used as an assessment tool to measure students' analytical thinking skills and review the thinking process by describing contextual problems (science), interpreting these problems in a simpler form in the form of images, symbols, or mathematical modeling (engineering), which can utilize technology in their solution so that students become accustomed to and proficient in its use (technology), and solve the problems based on mathematical concepts used to conclude (mathematics) on trigonometric comparison material. Four essay questions were developed. Each question contains multiple components of the three indicators of analytical

thinking skills (distinguishing, organizing, and connecting) and contains several STEM components, is highly complex, and focuses on quality over quantity, which can later be used in 2 lessons (2 x 45 minutes). Furthermore, the answers provided by students can be reviewed in greater depth. The data analysis technique used in this study is quantitative data analysis, which aims to analyze data obtained from expert validation and empirical validation at the development stage, and qualitative data analysis in the form of criticism or suggestions from experts. Qualitative data aims to identify responses, critiques, or suggestions that can assist in the development of test instruments.

The developed test items were validated through content validation, face validation, and construct validation by three experts (expert judgment), namely lecturers from the State University of Jakarta and a teacher practitioner with a master's degree in mathematics education. The results of the expert review were used to assess the validity of the test instruments, which were then calculated using the following formula: (Riduwan, 2015)

$$\text{Score percentage} = \frac{\text{Total score obtained}}{\text{Maximum score}} \times 100\%.$$

Based on the calculation result, they were then interpreted according to the following criteria:

**Table 1. Validity Score Percentage Criteria**

Percentage Score	Interpretation
$80\% < x \leq 100\%$	Highly Valid
$60\% < x \leq 80\%$	Valid
$40\% < x \leq 60\%$	Sufficiently Valid
$20\% < x \leq 40\%$	Less Valid
$0\% < x \leq 20\%$	Not Valid

Next, empirical testing of the test instrument was conducted using the Product-Moment Correlation developed by Karl Pearson. The decision criteria used the table  $r$  with a significance level of  $\alpha = 0,05$  on both sides, and the decision was declared valid if  $r_{\text{calculated}} \geq r_{\text{table}}$ .

After that, reliability was calculated using Cronbach's Alpha formula to determine the consistency of the instrument. This aims to provide a high level of confidence in the test instrument. The formula used is: (Lestari & Yudhanegara, 2015)

$$r = \left( \frac{n}{n-1} \right) \left( 1 - \frac{\sum S_i^2}{S_t^2} \right).$$

Explanation:

$r$  : reliability coefficient,

- $n$  : number of items,  
 $S_i^2$  : variance of item  $i$  score,  
 $S_t^2$  : variance of total score.

By determining the variance  $S^2$  of each data, using the formula:

$$S_i^2 = \frac{\sum X_i^2 - \frac{(\sum X_i)^2}{N}}{N}, \text{ for the subject, } N > 30$$

In test instruments that are declared valid and reliable, obtained results are then viewed from the following interpretive aspects: (Lestari & Yudhanegara, 2015)

**Table 2. Criteria for the Correlation Coefficient for the Validation and Reliability**

Correlation Coefficient	Interpretation
$0,90 \leq r_{xy} \leq 1,00$	Very Accurate/Very Good
$0,70 \leq r_{xy} < 0,90$	Accurate/Good
$0,40 \leq r_{xy} < 0,70$	Fairly Accurate/Fairly Good
$0,20 \leq r_{xy} < 0,40$	Inaccurate/Poor
$r_{xy} < 0,20$	Very Inaccurate /Very Poor

After calculations were made based on empirical validity and reliability, the test instruments were then calculated for their level of difficulty. This calculation aimed to determine whether the test items were classified as too easy. The formula used to determine the level of difficulty is as follows: (Lestari & Yudhanegara, 2015)

$$IK = \frac{\bar{X}_i}{SMI}$$

Explanation:

- $IK$  : difficulty index of the test item,  
 $\bar{X}_i$  : average student score on a question,  
 $SMI$  : Ideal Maximum Score, the maximum score obtained by students if they answer the item correctly (perfectly).

The calculated results are then classified based on the provisions outlined in the following table:

**Table 3. Instrument Difficulty Index Criteria**

IK	Interpretation
$IK = 0,00$	Too Difficult
$0,00 < IK \leq 0,30$	Difficult
$0,30 < IK \leq 0,70$	Moderate
$0,70 < IK < 1,00$	Easy
$IK < 1,00$	Too Easy

## RESULTS AND DISCUSSION

The results of this study will be discussed in accordance with the stages of test instrument development, namely 1) Define, 2) Design, 3) Develop (Maydiantoro, 2021).

### Define stage

In the define stage, several components were carried out, such as initial objective analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives. It began with the findings of problems that occurred at SMAN 1 Rawamerta by giving students several questions containing contextual problems on trigonometric comparison material. The analysis used referred to analytical thinking ability indicators and several STEM components. The students' answers showed that they were not yet able to describe the problems created. This was evident from the students' answers shown in Figure 2. The students' answers did not show STEM components in their solutions that could interpret the problems. This suggests that the students were not yet accustomed to answering questions systematically, which would make it easier for them to solve the problems raised. The question also did not show the significance of observing the distance between the helicopter and the building, so this question did not show the complete science component.

Upon further review, it was found that the questions given to students were multiple-choice questions, which, according to the results of the study, only tested cognitive skills such as remembering and understanding. The application questions are still in the category of routine questions aimed at direct calculation, and other practice questions are given based on the books used. Thus, teachers have not shown the ability to create their own test instruments that can build students' ability to think analytically from the context and content of the problems given. Based on the problems encountered, solutions are needed to improve the test instruments. Therefore, there is a need to develop test instruments that can measure analytical thinking and reasoning skills based on STEM components that can help students solve the problems given. Thus, these test instruments can also be used as evaluation materials that can analyze students' abilities or learning processes.

Gambar tersebut menunjukkan seorang anak yang berada pada jarak 36 meter dari kaki sebuah gedung. Ia mengamati puncak gedung dan helikopter di atasnya dengan sudut elevasi masing-masing  $30^\circ$  dan  $45^\circ$ . Tinggi helikopter tersebut dari atas gedung adalah

$\tan 45^\circ = \frac{a}{36}$   
 $1 = \frac{a}{36}$   
 $1 = \frac{a}{36}$   
 $a = \frac{36}{36}$

$\tan 30^\circ = \frac{a}{36}$   
 $= \tan 30^\circ = \frac{1}{\sqrt{3}} = \frac{a}{36}$   
 $- a = \frac{1}{\sqrt{3}} \cdot 36$

i. Siswa belum mampu membedakan masalah ke dalam notasi pemodelan matematika yang lebih sederhana, belum mampu menguraikan masalah kontekstual dengan sempurna dan belum mampu mengidentifikasi keseluruhan dari informasi yang diberikan melalui representasi gambar yang dibuat

ii. Siswa belum mampu menunjukkan keterkaitan potongan dari informasi yang diberikan, sehingga terjadi kesalahan dalam merepresentasikan gambar sehingga penyelesaiannya tidak sistematis

iii. Siswa belum mampu menunjukkan tujuan dan tidak memberikan kesimpulan akhir dengan jelas

Figure 2. Student Answers

### Design Stage

This stage involves the process of designing test instruments, beginning with the design of a test instrument grid used to measure analytical thinking skills. The grid refers to analytical thinking ability indicators and is adjusted to STEM components. This grid is designed to see the suitability of thinking ability indicators, the STEM components inserted, with the material on trigonometry comparison. The test instrument grid can be seen as follows:


**Table 4. STEM-based Test Instrument Grid with Analytical Thinking Skills**

Analytical Thinking Skills Indicators	Indicators of Trigonometric Ratios Learning in Right-Angled Triangles	STEM Components	Question Number
Distinguishing, Organizing, Connecting	Students can identify and explain the relationship between trigonometric angles by developing a solution strategy, and determine the purpose and relationship of the information provided using trigonometric ratio concepts.	Based on the available statements, students are asked to construct this statement based on trigonometric values, including their calculations (E), calculations are permitted to use a scientific calculator (T), and matching based on trigonometric angle values (M).	1
Distinguishing, Organizing, Connecting	Students can identify and explain the relationship between the given trigonometric contextual problems by developing a solution strategy involving right triangles	The contextual problem provided contains information related to seesaws (S), calculations are permitted using a scientific calculator (T), a diagram representing the contextual problem (E), and drawing	2

Distinguishing, Organizing, Connecting	<p>and providing conclusions from the problems. Students can identify and explain the relationship between the given trigonometric contextual problem by developing a solution strategy using the angle of depression involving a right-angled triangle and providing a conclusion from the problem.</p>	<p>conclusions based on the results of the investigation (M). The contextual problem (phenomenon) presented in the question and the concepts of measuring in centimeters and meters (S), calculations are permitted to use a scientific calculator (T), image representing contextual problems (E), the angle of depression or angle of elevation to be used in the calculation, based on the diagram and calculation to solve the problem (M).</p>	3
Distinguishing, Organizing, Connecting	<p>Students can identify and explain the relationship between the given trigonometric contextual problems by developing a solution strategy using the angle of depression involving a right triangle and providing a conclusion to the problem.</p>	<p>The distance of the object to the mirror is equal to the distance of the mirror to the image (fact) and the story problem given in the question (S), calculations are permitted using a scientific calculator (T), the diagram shown in the problem (E), placement of angles in the problem and calculations to answer the problem (M).</p>	4

Based on the grid that has been designed, the test instruments are then designed and can be seen as follows:

**Table 5. Example of Developed Questions**

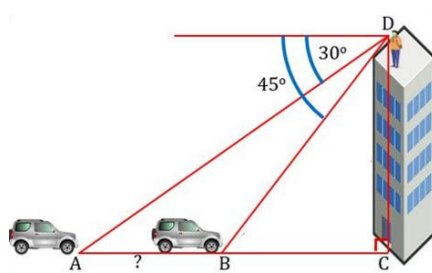
No.	Questions
2	<p>The at the following picture!</p> 
<p>Have you ever ridden a seesaw like the one in the picture above? A seesaw functions as a lever that can be used as a children's toy, with a fulcrum located in the middle of the board. Balance on the seesaw is key, but to play on it, weight is needed on both ends, which are then moved up and down according to the laws</p>	

of physics. The height of the fulcrum on the seesaw is 60 cm. An ideal seesaw is made of sturdy material, with the height of the end shown at point T not too high and the distance between the board and the fulcrum not too close. This ensures that the game can be enjoyed safely and comfortably. Based on the information above, examine the following statements and provide evidence for your calculations...

- (1) An ideal seesaw has an angle of  $\alpha = 30^\circ$
- (2) An ideal seesaw with an angle of  $\alpha = 45^\circ$
- (3) An ideal seesaw with an angle of  $\alpha = 60^\circ$

From the rooftop or top of a building, someone is observing a car driving on the road below. Initially, the car is visible at a depression angle of  $30^\circ$ , and a moment later at  $45^\circ$ . The observer is 170 cm tall, while the height of the building is 51 m. What is the displacement of the car from its initial position to its current position?

3



The assessment instrument used is the scoring rubric for the analytical thinking ability test developed: (Wijayanti et al., 2022)

**Table 6. Analytical Thinking Ability Test Scoring Rubric**

Analytical Thinking Ability Indicators	Description	Score
Distinguishing, organizing, and connecting	Students can answer questions and master the three indicators of analytical thinking skills accurately	4
	Students can answer questions and master the three indicators of analytical thinking skills, but there are still errors	3
	Students are only able to master 2 indicators of analytical thinking skills accurately	2
	Students are only able to master one indicator of analytical thinking skills accurately.	1
	Students are unable to master all three indicators of analytical thinking skills.	0

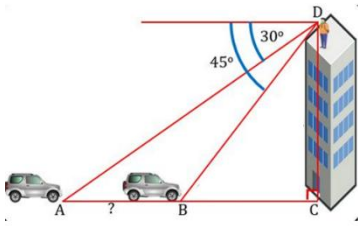
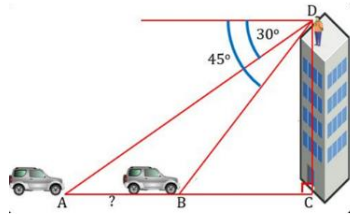
## Development Stage

During the development stage, validation was carried out by experts. Based on the developed test instruments, there were a few revisions, which are outlined in the following table:

**Table 7. Summary of Validator Improvement Suggestions**

Validator	Improvement Suggestions			
	Question 1	Question 2	Question 3	Question 3
Validator 1	-	-	-	-
Validator 2	-	-	-	-
Validator 3	-	-	Add contextual stories with students (what is the purpose of the activity)	-
Validator 4	-	-	-	-

**Table 8. Question Instrument Improvement**

No.	Before Improvement	After Improvement
3	<p>From the rooftop or top of a building, someone is observing a car driving on the road below. Initially, the car is visible at a depression angle of <math>30^\circ</math>, and a moment later at <math>45^\circ</math>. The observer is 170 cm tall, while the height of the building is 51 m. What is the displacement of the car from its initial position to its current position?</p> 	<p>At certain times, several building guards check specific areas to ensure that the environment is safe and under control. One guard is assigned to check the rooftop area (top of the building). While carrying out his duties, the guard stops for a moment to enjoy the air and observe a car driving down the road. At first, the car appeared to have a depression angle of <math>30^\circ</math>, and a moment later, it appeared to have an angle of <math>45^\circ</math>. The guard is 170 cm tall, while the height of the building is 51 m. What is the distance traveled by the car from its initial position to its current position?</p> 

Based on the assessment and improvement suggestions by the validators, there are minor improvements to refine the developed test instrument. After obtaining the scores from the validators, they are calculated based on the assessments given by each validator.

**Table 9. Summary of Validator Evaluations**

Validator	Total Score	Score Obtained	Percentage	Criteria
Validator 1	16	16	100%	Highly Valid
Validator 2	16	16	100%	Highly Valid
Validator 3	16	15	93,75%	Highly Valid
Validator 4	16	16	100 %	Highly Valid
Conclusion			97,92%	Highly Valid

Table 9 above shows that the test instrument has valid results with very valid criteria.

Furthermore, a limited trial was conducted. This trial was given to 31 students in grade XI. The results of these answers were used as data to determine the value or interpretation of empirical validity, reliability, and the level of difficulty of the questions.

**Table 10. Summary of Empirical Validity Results of the Test Instrument**

Test Item	$r_{\text{calculated}}$	$r_{\text{table}}$	Criteria
1	0,7182	0,3550	Valid
2	0,7283	0,3550	Valid
3	0,7226	0,3550	Valid
4	0,7997	0,3550	Valid

**Table 11. Instrument Reliability Recapitulation Results**

Reliability Coefficient	Interpretation
0,7363	Accurate/Good

**Table 12. Test Instrument Difficulty Level Recapitulations Result**

Test Item	Value	Interpretation
1	0,8145	Easy
2	0,6774	Moderate
3	0,6371	Moderate
4	0,6855	Moderate

Based on the validity results in Table 10, it was found that each item had valid results. This shows that the test instrument can be confirmed to measure what it should measure (Lestari & Yudhanegara, 2015). Students can interpret the contextual problems contained in the items into STEM components. This is shown in Figure 3. Part (1) of the figure shows the students' answers in terms of their approach, which is a component of science and analytical thinking at the differentiation stage, where students can understand the contextual problems given by distinguishing the important parts needed to lead to a solution strategy.

Furthermore, part (2) shows that students can transform these thoughts and express them in simple mathematical models through pictures, symbols, or simple written descriptions that can represent the problem (engineering). In this section, students can design/construct/create their own models based on their own ideas and ability to organize a problem. Then, based on the students' answers, the next step can be taken, which is the ability to connect, starting from determining the objective based on the problem asked, the solution strategy using the appropriate concept, and determining the conclusion of the problem given. In section (3), the ability to connect with mathematics in STEM components is created. More specifically, in section (4) on the use of technology in STEM components, students are given the freedom to become skilled in using scientific calculators or creating their own solutions with the help of trigonometric value tables that students describe independently. Therefore, in solving each question, the systematic nature of analytical thinking and STEM components demonstrated in problem-solving can be ensured. Thus, the

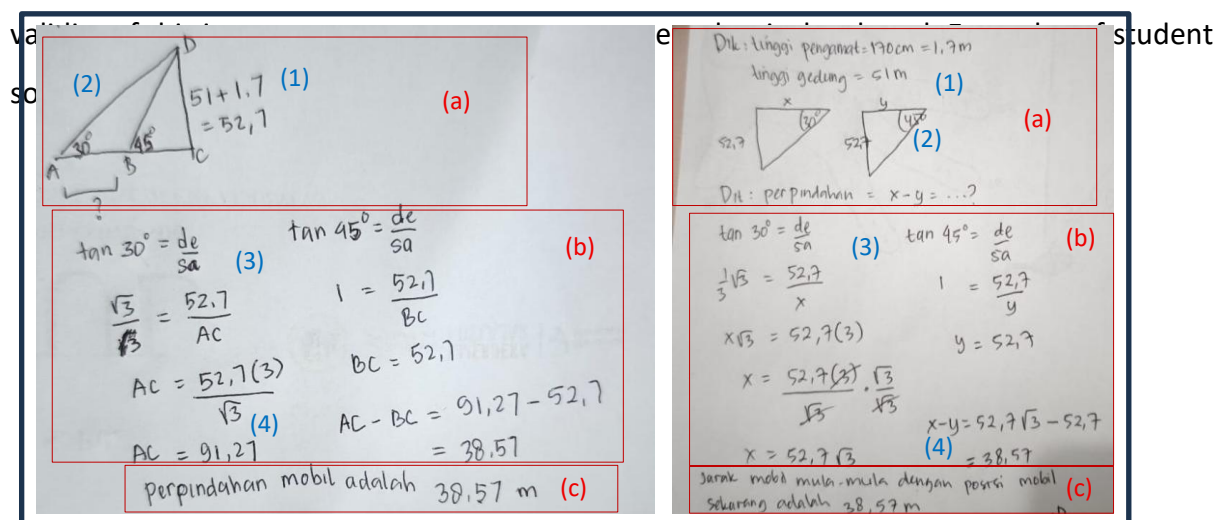


Figure 3. Students' Answers on The Test Instrument

The reliability shown in Table 11 has a reliability value of 0.7363. Based on the correlation coefficient group, the calculation results are categorized as good. This indicates that the test instrument is stable and reliable in measuring abilities through test instruments (Lestari & Yudhanegara, 2015). Furthermore, the level of difficulty of the questions in Table 12 shows that there is one question with an easy level of difficulty and three questions with a moderate level of difficulty. This is in accordance with the opinion of Lestari and

Yudhanegara (2015) on the level of difficulty of questions (Lestari & Yudhanegara, 2015). Therefore, overall, this test instrument can be said to have good intensity.

Based on the results of development and testing in a limited group, it can be concluded that the test instrument containing STEM components has good validity, is valid according to experts and empirical validity calculations, has a good level of reliability, and has an easy and moderate level of difficulty in measuring analytical thinking skills. Thus, this test instrument can be used as a measuring tool to measure students' analytical thinking skills.

## CONCLUSION

This test instrument can demonstrate each indicator of analytical thinking skills by involving STEM components that can help students solve the problems given. Based on the questions provided, students can separate the important parts and find the relationship between the known information and the questions asked. The STEM components that are part of the solution make it easier for students to obtain a simpler interpretation. Thus, each student can solve in various ways, which also allows for the development of other thinking skills. Therefore, this test instrument is suitable for measuring analytical thinking skills in 10th grade trigonometry material.

One suggestion is that this test instrument can be tested on a larger group and used as an example to measure analytical thinking skills in other materials.

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