

## Analysis of student errors in solving comparative trigonometry problems of right-angled triangles based on watson's criteria

Cindivia Putri Bayu<sup>1\*</sup>, Dian Devita Yohanie<sup>2</sup>, Aprilia Dwi Handayani<sup>3</sup>

<sup>1,2,3</sup>Departement of Mathematics Education, Universitas Nusantara PGRI Kediri. Jalan KH. Acmad Dahlan No 76 Kota Kediri, Indonesia.

E-mail : <sup>1</sup> [cindiviaputri2000@gmail.com](mailto:cindiviaputri2000@gmail.com)\*, <sup>2</sup> [diandevita@unpkediri.ac.id](mailto:diandevita@unpkediri.ac.id),  
<sup>3</sup> [apriadiadwi@unpkediri.ac.id](mailto:apriadiadwi@unpkediri.ac.id)

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\* Corresponding author.

**ABSTRACT:** This study aims to analyze the location of students' errors in problem solving and the causal factors based on Watson's criteria. This type of qualitative descriptive research, with the subject of three students of class X AKL 1 taken based on certain considerations according to the criteria or can be called purposive sampling technique. Data collection techniques include direct observation in schools, interviews with subjects and documentation. Triangulation techniques used for data analysis include data reduction, presentation and conclusion drawing. From the results of the analysis, it was found that four types of errors were located in improper procedures, indirect manipulation, missing data and missing conclusions. The cause of the error is students lack understanding of material concepts, being careless in reading questions, forgetting formulas, being in a hurry, and new factors are found, namely students use other paper to write down the completion steps. The results of the study can explain in detail the errors made by students in solving problems, so that it can minimize the occurrence of similar errors and improve the learning process of mathematics.

**Keywords:** Error analysis; trigonometric comparisons; Watson criteria

### Analisis kesalahan siswa dalam penyelesaian soal perbandingan trigonometri segitiga siku-siku berdasarkan kriteria watson

**ABSTRAK:** Penelitian bertujuan menganalisa letak kesalahan siswa dalam penyelesaian soal serta faktor penyebabnya berdasarkan kriteria Watson. Jenis penelitian deskriptif kualitatif, dengan subjek tiga siswa kelas X AKL 1 yang diambil berdasarkan pertimbangan tertentu sesuai kriteria atau bisa disebut teknik *purposive sampling*. Teknik pengumpulan data meliputi observasi secara langsung disekolah, wawancara terhadap subjek serta dokumentasi. Triangulasi teknik digunakan untuk analisis data meliputi reduksi data, penyajian dan penarikan kesimpulan. Dari hasil analisis ditemukan empat jenis kesalahan terletak pada prosedur tidak tepat, manipulasi tidak langsung, data hilang dan kesimpulan hilang. Penyebab kesalahan yaitu siswa kurangnya pemahaman terhadap konsep materi, kurang teliti dalam membaca soal, lupa rumus, terburu-buru, dan ditemukan faktor baru yaitu siswa menggunakan kertas lain untuk menuliskan langkah-langkah penyelesaian. Hasil penelitian dapat menjelaskan secara rinci kesalahan yang sering dilakukan siswa dalam penyelesaian soal, sehingga dengan ini dapat meminimalisir terjadinya kesalahan serupa dan dapat memperbaiki proses pembelajaran matematika.

**Kata Kunci:** Analisis kesalahan; perbandingan trigonometri; Kriteria Watson

## INTRODUCTION

In mastering science and technology, mathematics has a very important role as a basic science, whether in terms of application aspects or logic aspects. Because of its role, mathematics occupies a compulsory subject in the realm of education. Mathematics is given

from elementary school to high school (Hawa, 2020). Therefore, the time of mathematics subjects have the most frequency than other subjects given.

In daily life, all activities that humans do are inseparable from mathematics. According to Hudojo in (Khotimah, Yuwono, & Rahardjo, 2016) states that mathematics is knowledge which is the basis for working in life in the era of globalization. Learning mathematics provides direct experience for students to be involved in observing learning in everyday life both physically and socially that is expected to provide meaningful learning outcomes. In the process of learning mathematics, it should provide students with provisions in achieving certain competencies, so that students' needs can be fulfilled, namely understanding a concept of the problem faced so that they can solve it (Novianti & Riajanto, 2021). In order for mathematics learning to be meaningful, a comprehension is needed.

Understanding in question is not just getting information, but they must understand and be able to apply it in problem solving. This is confirmed by Hiebert and Carpenter (1992) in (Jatisunda & Nahdi, 2019) stated that understanding mathematics is one of the ideas that can be accepted in mathematics education. Likewise, according to Hung-His Wu (1999) in (Jatisunda & Nahdi, 2019) stated that in the case of mathematics, accuracy, clarity and useful skills are needed as a means of understanding mathematical concepts.

Through the results of student work sheets, it can be observed directly the errors made in solving problems. Learning difficulties often occur when obstacles are found in the learning process. This cannot be handled if the same mistakes are always made by students. Teachers can analyze student worksheets to be able to find out what mistakes have been made by students and uncover the causes of these errors (S. Wulandari & Gusteti, 2020). According to Subanji and Mulyoto in (Widodo, 2017) there are several kinds of triggers for errors such as errors in understanding concepts, drawing conclusions, solving steps, and understanding problem language.

In research (Csáky, Szabová, & Naštická, 2015) suggested that it is necessary to analyze student errors, because many students made similar mistakes when given a math assignment. (Cahyani & Aini, 2021) stated that one way to overcome errors in problem solving is to find the source of the cause of students making mistakes so that errors can be corrected. In his research, errors in solving trigonometric problems received less attention from mathematics teachers to take corrective action.

Likewise with research (Palayukan & Pelix, 2018) stated that there were many mistakes made by students, this was because improvements were not immediately made on teacher learning, only seeing the final results without returning to the causes of students making mistakes. The same thing was said (Novianti & Riajanto, 2021) many students make mistakes because of difficulties in solving trigonometry problems. (El-khateeb, 2016) affirming that the errors analyzed must be presented in detail which is given to the mathematics teacher as a form of feedback for learning improvement.

Based on previous research and the results of observations made in mathematics learning in Class X AKL 1 SMK PGRI 2 Kediri in April 2021, it was found that many students complained that mathematics was difficult, the difficulty experienced by students was to

apply the trigonometric comparison value formula on a right triangle to the problem thus causing errors in problem solving. According to Kariadinata in (Rachman, 2020) argued that trigonometry is one part of mathematics related to angles and comparisons of trigonometric values that requires accuracy and foresight in thinking.

If errors are not immediately addressed, it will have an impact on student achievement, therefore as a solution it is necessary to analyze the causes of errors based on Watson's criteria. The research aims to find out the location of student errors in solving problems and to explain in detail the factors causing them so that they can be corrected in the learning process. The novelty of this research can find out the mistakes that are often made by students in solving problems, thereby minimizing students making similar mistakes and increasing effective and efficient learning.

To see errors in solving trigonometric comparison problems in right triangles through the data that has been obtained, the researchers analyzed using the Watson criteria. The following are indicators of student error based on Watson's criteria:

Table 1. Error Factor Indicator Based on Watson Criteria

Watson Criteria	Indicator	Reason
Incorrect data	<ul style="list-style-type: none"> <li>misplaced data on variable</li> <li>data does not match</li> </ul>	<ul style="list-style-type: none"> <li>inaccuracy in the process</li> <li>do not understand the meaning of the question</li> </ul>
Incorrect procedure	<ul style="list-style-type: none"> <li>Using the wrong formula</li> <li>Do not write down the steps when solving problems</li> </ul>	<ul style="list-style-type: none"> <li>In solving problems, do not understand the concept</li> <li>do not understand how to write the formula steps of the problem</li> </ul>
Lost data	<ul style="list-style-type: none"> <li>Incomplete data entered</li> </ul>	<ul style="list-style-type: none"> <li>In presenting the data less accurate</li> </ul>
Lost conclusion	<ul style="list-style-type: none"> <li>Do not use existing data when making conclusions</li> </ul>	<ul style="list-style-type: none"> <li>When making conclusions do not understand how to process data</li> </ul>
Response level conflict	<ul style="list-style-type: none"> <li>Not ready when solving problems</li> </ul>	<ul style="list-style-type: none"> <li>Not preparing for a test</li> </ul>
Indirect manipulation	<ul style="list-style-type: none"> <li>Illogical reasons when solving problems</li> <li>Don't understand the question given</li> </ul>	<ul style="list-style-type: none"> <li>Confused in giving reasons when solving problems</li> <li>Confused in interpreting the meaning or meaning of the problem</li> </ul>
Skill hierarchy problem	<ul style="list-style-type: none"> <li>Errors made in calculating</li> <li>Mistakes made when using algebraic ideas</li> </ul>	<ul style="list-style-type: none"> <li>Careless in the process of calculating</li> <li>Self-doubt in writing the results of his thoughts</li> </ul>

Sumber : (Cahyani & Aini, 2021)

## METHOD

The type of research conducted is descriptive qualitative because it is intended to analyze errors in problem solving and the factors that cause students to make mistakes. The research was conducted at SMK PGRI 2 Kediri, Bandar Lor, District Mojoroto, Kediri, East Java, from April to May 2021. The subjects of this study were three students of class X AKL 1 SMK PGRI 2 Kediri in the even semester of the 2020/2021 academic year. It was taken based on certain considerations in accordance with the criteria or can be called a purposive sampling technique (Siyoto & Sodik, 2015). The first student was given the initials MPW representing the low error rate, the second student was given the initials DDP representing the medium error rate and the third student was given the initial DMW representing the high error rate.

Data collection techniques include direct observation at school, interviews with subjects and documentation (Sugiyono, 2009). In checking the validity of the data, researchers used triangulation techniques. Triangulation Technique is the use of various ways to get data directly to the data source. Testing the data is done directly to the subject. In obtaining data, it can be done by combining various techniques (Helaluddin & Wijaya, 2019).

The data analysis technique used was in accordance with the steps of Miles and Huberman in (Najib, 2019) include: a. Data reduction, by correcting student work sheets, describing student errors and reducing interview results. b. The presentation is carried out using the results of student work as interview material which is then recorded through a voice recorder. c. Drawing conclusions, based on the results of student work and interview results then it was analyzed, so that conclusions can be drawn in the form of a description of error analysis based on Watson's criteria.

## RESULTS AND DISCUSSION

### Research result

Categorization of student error levels based on the results of student worksheet analysis in accordance with Watson's criteria so as to get representatives of each low, medium and high error rate. The error found lies in item number 2 of 2 description questions, the questions can be seen in Picture 2.

2. Pada segitiga siku-siku  $ABC$ , diketahui  $\tan \alpha = \frac{5}{12}$ . Tentukan
- |                  |                                  |
|------------------|----------------------------------|
| a. $\sin \alpha$ | d. $\cot \alpha$                 |
| b. $\cos \alpha$ | e. $\operatorname{cosec} \alpha$ |
| c. $\sec \alpha$ |                                  |
- Penyelesaian :

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Picture 1. Question Description Number 2

Table 2. Student Error Analysis Based on Error Category Watson Criteria

Place Error	Subject		
	MPW	DDP	DMW
Incorrect data	-	-	-
Incorrect procedure	√	-	√
Lost data	-	-	√
Lost conclusion	-	√	-
Response level conflict	-	-	-
Indirect manipulation	-	√	√
Skill hierarchy problem	-	-	-

From table 2, MPW students have a low error rate with incorrect procedural errors, DDP students have a moderate error rate which lies in missing conclusions and indirect manipulation, while DMW students have a high error rate which lies in incorrect procedures, missing data and indirect manipulation. The following is a description of the errors made by students in solving problems :

2.  $\tan \alpha = \frac{5}{12}$

$AC = \sqrt{5^2 + 12^2}$

$= \sqrt{25 + 144}$

$= \sqrt{169}$

$= 13$

a.  $\sin \alpha = \frac{5}{13}$

b.  $\cos \alpha = \frac{12}{13}$

c.  $\sec \alpha = \frac{13}{12}$

d.  $\cot \alpha = \frac{12}{5}$

e.  $\operatorname{cosec} \alpha = \frac{12}{5}$

Picture 2. MPW Student Answer Sheet

It can be seen from Picture 2 which is the answer from MPW students, with a low error rate which lies in the incorrect procedure. MPW students rewrote the information obtained from the problem and wrote down the steps in finding the hypotenuse using the Pythagorean theorem, but MPW students did not describe a triangle  $ABC$  and MPW students were not right in solving problem number 2 part e, namely MPW students were not right in applying the concept of trigonometric comparison value to the problem, it can be seen in Picture 2 that the value  $\operatorname{cosec} \alpha = \frac{12}{5}$  should be  $\operatorname{cosec} \alpha = \frac{13}{5}$ . The following is an excerpt from the results of interviews with MPW students conducted on May 3, 2021 in order to find out the factors that caused MPW to make mistakes with the wrong type of procedure.

CPB : "Why do you not draw a right triangle?"

MPW : "Yeah forgot" (smiling)

CPB : "Then, are the value of the trigonometric ratio of cotan the same or not cosec ?"

MPW : "It is the same"

CPB : "If cotan what for what? or the opposite of what?"

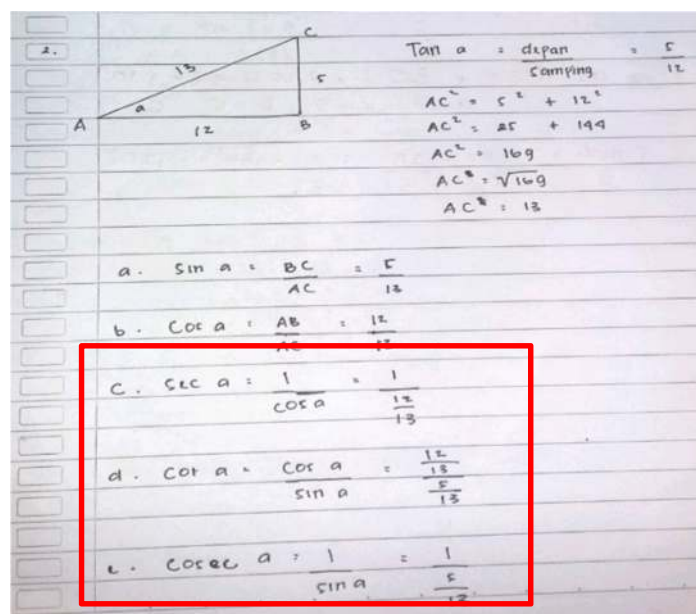
MPW : "It is tan"

CPB : "That's right, then if cosec ?"

MPW : "The opposite of sin "

CPB : "Does it mean the same or different between cotan with cosec ?"

MPW : "It is different" (smiling)



Picture 3. DDP Student Answer Sheet

DDP is a student with a moderate error rate category, it can be seen from Picture 3 which is the answer from DDP students. Based on the answer sheet, DDP students are correct in writing down the things that are known on the problem, there are steps in finding the value  $AC$  using the Pythagorean theorem and also describes a triangle  $ABC$  but DDP students are less precise in giving the final answer. Based on Watson's criteria, DDP students made mistakes, namely missing conclusions and indirect manipulation, it can be seen in Picture 3 parts c, d and e that DDP students did not simplify their final answers, DDP students should be able to write down the correct final answer in the form of simplifying fractions. The following is an excerpt from an interview with DDP students conducted on May 3, 2021 to find out the factors causing the error.

CPB : "Why are the answers to questions number 2 c, d, and e not simplified immediately?"

DDP : "Hurry in doing" (smiling)

CPB : "It means that if you simplify the result, how much? for number 2 c first"

DDP : " $\frac{12}{5}$ "

CPB : "If the division is in a fraction, it must be converted into a multiplication form, isn't it?"

- DDP : "Yes"  
 CPB : "So, what is the result?"  
 DDP : " $\frac{13}{12}$ "  
 CPB : "For question 2 d, what is the result?"  
 DDP : " $\frac{12}{5}$ "  
 CPB : "How about 2 e?"  
 DDP : " $\frac{13}{5}$ "

2. a)  $\sin a = \frac{\text{depan}}{\text{miring}} = \frac{5}{13}$       d)  $\cos a = \frac{\text{samping}}{\text{depan}} = \frac{12}{5}$   
 b)  $\cos a = \frac{\text{samping}}{\text{miring}} = \frac{12}{13}$       e)  $\text{cosec } a = \frac{\text{miring}}{\text{depan}} = \frac{13}{5}$   
 c)  $\sec a = \frac{\text{miring}}{\text{samping}} = \frac{13}{12}$

Picture 4. DMW Student Answer Sheet

DMW is a research subject with a high error rate category. Based on the results of the completion of number 2 in Figure 4, DMW students made an error based on Watson's criteria which was located in an incorrect procedure, DMW did not use inappropriate steps in solving the problem and did not describe a right triangle ABC, the second error lies in missing data because it did not rewrite the information that is known in the question and the last is indirect manipulation, on worksheet number 2 part d DMW students write down the value  $\cos \alpha$  of even though the value sought is  $\cot \alpha$ . To find out why DMW students made the mistake, an interview was conducted on May 3, 2021, following the results of the interview.

CPB : "Why do you not write down the steps in solving problem and drawing triangles for number 2?"

DMW : "When working on it, write the steps on another paper, then put it on the answer sheet directly"

CPB : "From the question number 2 d, what is the answer?  $\cot \alpha$  or  $\cos \alpha$ ?"

DMW : " $\cos \alpha$ "

CPB : "let's look again about number 2 d"

DMW : " $\cot \alpha$ "

CPB : "Why do you not write down the data you already know on the question?"

DMW : "Forgot"

## Discussion

Based on the description of the analysis of student work and interviews that have been carried out, it was found the location of the student's error in solving the problem, namely the incorrect procedure carried out by MPW and DMW, students were less precise in applying the trigonometric comparison value formula to the given problem and students did not write down the steps in problem solving. The factor that causes students to make this mistake is that students lack understanding of concepts and forget formulas, so that they made mistakes in applying the formula to the questions given. The results of this study are comparable with research conducted by (Cahyani & Aini, 2021) the factor is not understanding the concept to solve the problem. Then (Palayukan & Pelix, 2018) revealed the factors causing this error, namely forgetting the formula so that they do not know the right steps in solving the problem. The same thing was stated in research (Ayarsha, 2016) that the causal factor is that students incorrectly determine the formula that must be used to solve the problem.

The second error was that DMW lost data, DMW did not rewrite the information that was known on the question, DMW should have been able to write it down on student work sheets. This is because DMW forgot, it was less thorough and rushed in doing the work. According to (Aisyah, Hariyani, & Dinullah, 2019) and (Anjeli & Irwan, 2019) students are careless and in a hurry to solve problems. In research (Wulandari, 2016) students do not understand the problem so that the data used is incomplete.

The next mistake that DDP makes missing conclusions, DDP did not simplify the final answer that should be simplified. Factors causing errors made by students are students who did not understand the concept of simplification of fractions so that students did not write down the conclusion of the answer. It is also expressed by (Aly, Sujadi, & Taufiq, 2019) and (Maryani & Chotimah, 2021) in his research that is not writing conclusions in the final answer. The same thing happened in research (Palayukan & Pelix, 2018) and (Saputri, Sugiarti, Murtikusuma, Trapsilasiwi, & Yudianto, 2018) students did not write the final conclusion because they did not understand the meaning of the question and assume that the final answer is not important.

The next is indirect manipulation, DDP and DMW used unreasonable reasons during the interview process for the results of the work and also manipulated the questions given. The cause of errors in problem solving is that students were confused about giving reasons for their work, lack of understanding of the questions given and inaccuracy so that they manipulated questions and answers, and being rush in solving questions. The same thing was revealed in the research (Dazrullisa & Hadi, 2021) that students are confused in using the reasons used to provide an explanation of the results of their work, inaccuracy in reading and completing their work. While research (Sanwidi, 2018) stated that the factors that cause students to give illogical reasons are used in explaining problem solving and are in a hurry because of time. The same thing happened in research (Santoso, Cholily, & Syaifuddin, 2021) the one who manipulated the calculation is applying the wrong formula so that the answer given is also wrong.



The recency of the factor causing the error was found in incorrect procedural errors and missing data, it is because students used other paper to write down the steps for solving the problem, so that on the student work sheet only the final results of their work were written. The results of the study can explain the causes of students often wrong in solving problems, so as to minimize the occurrence of similar errors and can improve student learning outcomes.

## CONCLUSION

Based on the results of the analysis and discussion that has been presented, it can be concluded that the location of the errors in solving trigonometric comparison problems in right triangles is an incorrect procedure due to students are lacking in understanding concepts and forgetting formulas, so they made mistakes in applying formulas  $\operatorname{cosec} \alpha$  and inappropriate steps. Lost data errors are caused by students forgetting to write down information, inaccuracy and in a hurry to solve problems. The error conclusion is because students do not understand the concept of simplification of fractions so that students made mistakes by not writing the final conclusion from the answer. Furthermore, indirect manipulation is caused by students were confused about giving reasons for the results of their work, not understanding the meaning of the questions and not being careful in reading the questions so they do manipulation, also rushing in solving problems by giving reasons that don't make sense.

The novelty in this study found the cause of students making incorrect procedural errors and missing data, it is because students used other paper to write down the work steps in solving problems, so that on the student work sheets only the results of their work were written. The results of the study can explain the mistakes that are often made by students in solving problems, so as to minimize the occurrence of similar errors and can improve student learning outcomes. The weakness of the research is that it only used one class so that the grouping cannot be done widely and it is expected that further research can improve the weaknesses.

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