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Profile of Conceptual Understanding of Trigonometric Identities in Grade 11 at Madani Integrated Model Public High School in Palu, Examined by Gender and High Mathematical Ability

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A B S T R A C T

This study aims to describe the profile of students' conceptual understanding of trigonometric identities in terms of gender among students with high mathematical ability. This is a descriptive study using a qualitative approach. The research subjects consisted of two 11th-grade students at Madani Palu Integrated Model Public High School: one female student and one male student who demonstrated high mathematical ability based on their report card grades and teacher recommendations. Research data were collected through a written essay-style test and semi-structured interviews, then analyzed using the Miles, Huberman, and Saldana model, which includes data condensation, data presentation, and drawing conclusions. Data validity was tested using the member check technique. The results of the study indicate that both subjects were able to meet the four indicators of conceptual understanding: restating concepts, classifying objects according to their properties, using and selecting appropriate procedures, and applying concepts or problem-solving algorithms. The female student tended to be more systematic in her problem-solving steps, while the male student demonstrated a broader and more efficient ability to relate concepts to one another. Thus, both groups demonstrated a good conceptual understanding of trigonometric identities, with distinct characteristics based on gender.

1. Introduction

The current era of the Fourth Industrial Revolution, characterized by the integration of digital, physical, and biological technologies, demands that people possess new abilities to adapt and compete in a globalized world (Kurniawan, 2025). Mathematics plays a crucial role in developing the logical, analytical, and critical thinking skills required in modern life (Setyawan & Purwanto, 2019). Furthermore,

mathematics provides a framework for thinking and organizing that helps students analyze information and make decisions logically (Setiawan & Sudana, 2019). Therefore, mathematics instruction must emphasize conceptual understanding that is, the ability to master the material, restate concepts in one's own words, and connect them to other concepts to solve problems (Febrianto et al., 2020).

One of the topics in high school mathematics is trigonometric identities, which are often considered difficult because they require mastery of various basic concepts. Students' difficulties in solving trigonometric identity problems are generally caused by a lack of understanding of mathematical concepts (Asdar et al., 2020). In addition, a lack of mastery of prerequisite concepts, errors in interpreting formulas, and carelessness in calculations are also factors contributing to students' low conceptual understanding (Kadir, 2019). To assess students' mathematical representation skills, indicators are needed that show the extent to which students can utilize these representations (Hardy, 2024).

To address these issues, teachers need to understand students' conceptual understanding profiles so they can design instruction tailored to their abilities. Research by Silvia et al. (2024) indicates that students' conceptual understanding of trigonometry varies widely, and misconceptions still persist. Results from interviews with mathematics teachers of 11th-grade students at Madani Palu Integrated Model Public High School also indicate that students still struggle to understand trigonometric identities because they tend to memorize formulas without understanding the underlying concepts. Based on these findings, this study aims to describe the conceptual understanding profile of trigonometric identities among 11th-grade students at Madani Palu Integrated Model Public High School, as examined in terms of gender and high mathematical ability.

Research by Nurani et al. (2021) shows that students with high self-efficacy are able to master all indicators of mathematical concept understanding, whereas students with moderate and low self-efficacy master only some of the indicators, depending on their level of self-confidence (Nurani et al., 2021). This study is relevant because it also examines students' conceptual understanding, but differs in the variables under consideration, namely gender and high mathematical ability. Fadzillah (2016) found that students still experience difficulties in determining mathematical models, applying the appropriate algorithms, and relating various mathematical concepts in the topic of linear equations in one variable (Fadzillah, 2016). The similarity between this study and that research lies in their shared focus on conceptual understanding; the difference is that the previous study examined difficulties in conceptual understanding, whereas this study examines conceptual understanding in problem-solving.

Komariyah et al. (2018) state that students with high learning interest have a better conceptual understanding of problem-solving than students with moderate or low learning interest. Students with low learning interest tend to be able only to restate concepts without continuing the problem-solving process (Komariyah et al., 2018). This study is relevant because it also examines students' conceptual understanding,

though it differs in the aspects under consideration specifically, learning interest as opposed to gender and high mathematical ability.

A profile is a description or portrayal of an object or individual presented in written or visual form that reflects actual conditions (Afrilia et al., 2022; Budiarti, 2018). According to Goleman, as cited in Sukma and Masriyah (2022), student profiles can help teachers tailor their teaching strategies. Meanwhile, Alwi (2022) also notes that a profile is a general overview that depends on the perspective from which it is viewed. Thus, a profile can be defined as a general description of the characteristics of the subject under study.

Comprehension is a person's ability to receive, understand, interpret, and rephrase information in their own words (Asmudik, 2021; Yolanda, 2020). In Bloom's taxonomy, comprehension is the ability to grasp the meaning of the material being studied. Therefore, understanding can be defined as the ability to think critically in identifying, explaining, relating, and applying a concept in daily life. Conceptual understanding is a student's ability to grasp the meaning of a concept, rephrase it in their own words, and connect and apply that concept to problem solving (Pratiwi, 2017). In mathematics education, conceptual understanding serves as a crucial foundation before students tackle more complex material and develop problem-solving skills.

According to Shadiq (2009), indicators of conceptual understanding include: (1) restating a concept, (2) classifying objects according to their properties, (3) providing examples and non-examples, (4) developing necessary or sufficient conditions, (5) using specific procedures or operations, and (6) applying concepts or problem-solving algorithms. This study used four indicators: restating a concept; classifying objects according to specific properties; using, applying, and selecting specific procedures or operations; and applying concepts or problem solving algorithms. The selection of these four indicators was aligned with the lesson plans and the trigonometric identity curriculum used at the school.

Trigonometric identities are equations that contain trigonometric ratios and hold true for any angle that meets the conditions. These identities are proven by manipulating one side of the equation until it equals the other side. Trigonometric identities consist of basic inverse relationships and basic ratio relationships, which are used to solve various mathematical problems. Conceptual understanding is crucial in the mathematics learning process, as it is a fundamental skill students must possess when learning mathematical concepts. If students do not have a solid grasp of mathematical concepts, they will view mathematics as a difficult subject. One of the goals of mathematics education is to understand mathematical concepts, including both concepts and algorithms, in a flexible, accurate, efficient, and precise manner when solving problems. The ability to understand concepts will help students solve mathematical problems.

Based on this background, this study aims to describe the profile of students' understanding of trigonometric identity concepts among 11th-grade students at Madani Palu Integrated Model Public High School who have high mathematical

ability, including both female and male students. This study is expected to provide a clear picture of the characteristics of students' understanding of trigonometric identity concepts based on gender differences among students with high mathematical ability.

2. Methodology

Types and Approaches to Research

This study is a descriptive study using a qualitative approach that aims to describe the profile of students' conceptual understanding of trigonometric identities through data in the form of words, behaviors, and observed activities of the subjects (Sugiyono, 2022).

Research Setting & Subjects

The study was conducted at Madani Palu Integrated Model Public High School, Mantikulore District, Palu City, Central Sulawesi Province, during the odd semester of the 2025/2026 academic year. The research subjects consisted of two 11th-grade students with high mathematical ability based on report card grades and teacher recommendations: one female student (RR) and one male student (VS). The selection of these subjects aimed to provide an in-depth understanding of the conceptual understanding of students with high mathematical ability (Sugiyono, 2022).

Types and Sources of Data

The research data consisted of qualitative data obtained from written tests and interviews regarding students' conceptual understanding of trigonometric identities. The data sources were 11th-grade students at Madani Palu Integrated Model State High School.

Research Instruments

The primary research instrument was the researcher, who served as the collector, analyst, interpreter, and reporter of the data (Sugiyono, 2022). The supporting instrument was an essay test on trigonometric identities that had been validated by experts to ensure the validity of its content, construct, and language.

Data Collection Techniques

Data collection was conducted through written tests and semi-structured interviews. The tests were used to assess students' conceptual understanding in solving trigonometric identity problems, while the interviews were conducted to obtain more in-depth information regarding students' thought processes (Sugiyono, 2022).

Data Validation

Data validity was tested using the member check technique, which involves confirming the interpretation of data with the research subjects to ensure that the data obtained aligns with the informants' intentions and possesses a high level of credibility (Sugiyono, 2022).

Data Analysis Techniques

Data analysis followed the model proposed by Miles, Huberman, and Saldana (2014), which includes: (1) data condensation, which is the process of selecting and simplifying data; (2) presenting the data in the form of a systematic description; and (3) drawing and verifying conclusions based on the results of the tests and interviews to answer the research questions (Miles, Huberman, & Saldana, 2014).

3. Result and Discussion

Result

This chapter presents the research findings regarding the understanding of trigonometric identity concepts among 11th-grade students at Madani Palu Integrated Model Public High School. Based on the gender of the participants female and male students with high mathematical ability the findings are presented in accordance with the indicators used by the researcher.

Selection of Research Participants

The selection of participants in this study was based on their odd-semester report card grades in mathematics and recommendations from their mathematics teachers. Teachers recommended selecting students from Class XI-6, considering that these students were able to communicate effectively, express their opinions during the learning process, and were willing to participate in the study. The report card scores were then grouped into categories of high, moderate, and low mathematical ability, based on the mean ($\bar{x}$) and standard deviation (SD). According to the calculations, the mean mathematics score for Class XI-6 students was 81.02, with a standard deviation of 4.1. Thus, the criteria for grouping mathematical ability are as follows:

High KM	$N \geq \bar{x} + SD$	$\geq 85{,}12$
Medium KM	$\bar{x} - SD < N < \bar{x} + SD$	$76{,}92 < N < 85{,}12$
Low KM	$N \leq \bar{x} - SD$	$\leq 76{,}92$

Therefore, students who scored $N \geq 85.12$ were classified as having high mathematical ability. Students who scored $76.92 < N < 85.12$ were classified as having moderate mathematical ability. And students who scored $N \leq 76.92$ were classified as having low mathematical ability. This grouping is based on a statistical approach that uses the mean and standard deviation as the basis for categorizing academic ability, as explained by Sugiyono (2017), who states that classification

based on the mean and standard deviation is a method commonly used in quantitative research to group subjects based on specific achievement levels or abilities. The results of the grouping of students' abilities in Class XI-6 are shown in Table 1 below.

Table 1. Research Subjects

No	Student's Name (Inisial)	Report Card Grades	High Proficiency
1	RR	87	High
2	VS	99	High

Furthermore, the subjects selected for this study were only students with high mathematical ability, namely one of two students: one male student with the initials RR and one female student with the initials VS. Both fall into the high-mathematics-ability category VS (99) and RR (87) based on a score criterion of ≥85.12 according to Arikunto's (2010) classification. Subject selection followed the principles of qualitative research outlined by Creswell (2012). This selection was based on several considerations, including recommendations from the mathematics teacher, good communication skills during the learning process, and the students' willingness to participate in the study. Selecting participants based on these criteria is crucial in qualitative research because the participants' characteristics and openness significantly influence the completeness of the data collected (Sugiyono, 2017; Moleong, 2019). The following table presents the interviews with the research participants.

Table 2. List of Interview Questions

1.	Okay, since you've answered the question, I'd like to ask you a few questions now. Is that okay?
2.	So, what about the question, did you understand it?
3.	What did you understand from this question?
4.	Okay, so when you saw the problem, did you immediately think of a method to solve it?
5.	Oh, so because you saw that the pattern resembled an algebraic expression, you didn't immediately think of a trigonometric identity?
6.	Besides using the quadratic formula, are there other ways to solve this problem?
7.	So, what steps did you take to solve it?
8.	Okay, but if the form were different for example, $\sin^2 A + \cos^2 A = 1$ would you use the same method?
9.	Okay, moving on. Earlier you said the first step is to expand it. Now, try explaining the result of expanding $(\sin A + \cos A)^2$?
10.	And what about $(\sin A - \cos A)^2$?
11.	Okay, so you factored it like that, what's next?
12.	Okay, good, what's next?
13.	Okay, so now you've got the result: 4 sin A cos A. How do you know that result is correct?
14.	So, can we conclude that the trigonometric identity has been proven?

Results of Instrument Development

The research support instrument consists of one open-ended question on trigonometric identities, namely proving the equation ((\sin A+\cos A)^2 - (\sin A-

\cos A)^2 = 4\sin A\cos A). The question has been validated by Drs. Tegoeh S. Karimman, M.Pd., and deemed suitable for use.

Data Presentation and Credibility Testing

The research data were obtained from written tests and interviews, which were analyzed based on four indicators of trigonometric concept understanding according to Shadiq (2009), namely: (1) restating concepts, (2) classifying objects based on specific properties, (3) using or selecting appropriate procedures or operations, and (4) applying concepts or algorithms to solve problems. Data credibility was tested through member checking, which involved comparing the researcher's interpretation of the results with the research subjects' confirmation. To facilitate analysis, codes were used in the transcripts of the written tests and interviews. The written test codes consisted of T1 (written test), followed by the subject code (VS and RR), and the sequential number of the solution steps. Interview codes use PN (researcher), VS or RR (subject), followed by T1, the question number, and the sequential conversation number. For example, the code VST101 indicates an interview with subject VS regarding Written Assignment 1, question number 1, conversation number 01.

Presentation and Credibility Test of Subject RR's Data in Solving Trigonometric Identity Problems

Based on the written test results, RR was able to meet all four indicators of conceptual understanding namely, restating concepts, classifying objects according to their properties, selecting the appropriate procedure, and applying problem-solving algorithms as shown in Figure 1.

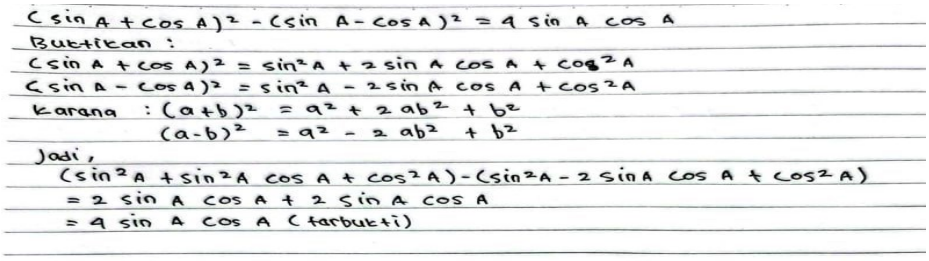

Figure 1. Subject RR's Responses

The researcher conducted interviews to gather further information. The interview results showed that RR understood the purpose of the problem and chose to use the algebraic formulas ((a+b)^2) and ((a-b)^2) because the problem resembled a quadratic equation.

> "I first expanded ((\sin A+\cos A)^2) and ((\sin A-\cos A)^2), then subtracted them, and finally simplified the result." (RRT114)

RR was also able to explain the simplification process leading to the result (4\sin A\cos A) and concluded that the trigonometric identity was proven to be true. All

of the researcher's interpretations were confirmed by the subject, RR. Thus, the interview data were deemed credible and suitable for use in the analysis.

Presentation and Credibility Test of Subject VS's Data in Solving Trigonometric Identity Problems

Based on the written test results, VS also met all indicators of conceptual understanding. VS was able to understand the problem, choose the appropriate solution strategy, and connect algebraic concepts with trigonometric identities.

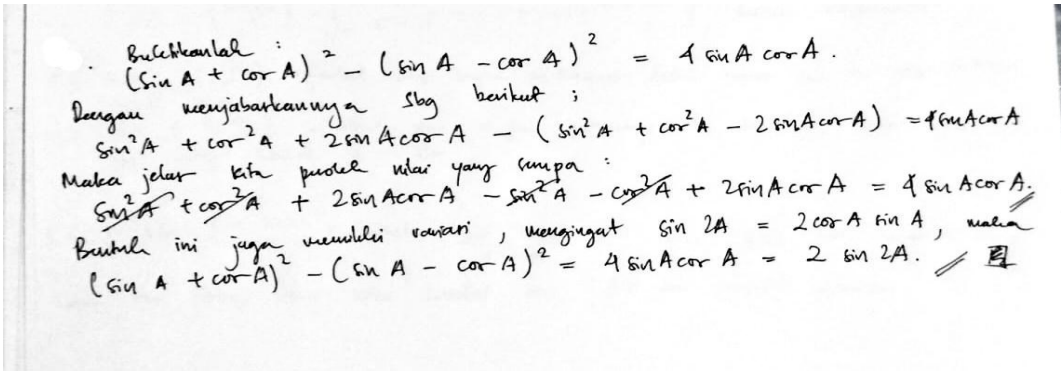

Figure 2. Subject VS Responses

In the interview, VS explained the reason for using algebraic identities:

> "It immediately occurred to me to first expand the expression using the algebraic identities ((a+b)^2) and ((a-b)^2)." (VST108)

VS also demonstrated a broader understanding by stating that the problem could be solved using the difference of squares formula and relating the final result to the double-angle formula.

> "I remembered the formula (2\sin A\cos A=\sin 2A), so (4\sin A\cos A=2\sin 2A)." (VST126)

VS was able to explain each step of the solution in a logical sequence to prove that both sides of the equation are equal. The member check results showed that all interview responses aligned with the subject's intentions, so VS's data was deemed credible.

Conclusion of Results

Based on the test and interview results, both RR and VS were able to meet all indicators of conceptual understanding according to Shadiq (2009), namely restating concepts, classifying objects according to their properties, using appropriate procedures, and applying problem-solving algorithms to trigonometric identity material. The member check results showed that all data obtained were credible.

Data Analysis

The data analysis aimed to describe the profile of conceptual understanding of trigonometric identities among 11th-grade students at Madani Palu Integrated Model Public High School, as viewed in terms of gender and high mathematical ability. The analysis was conducted in accordance with the stages outlined by Miles, Huberman, and Saldana (2014), namely data condensation, data presentation, and the drawing and verification of conclusions.

Data Analysis of Subject RR in Solving Problems Based on Indicators of Conceptual Understanding of Trigonometric Identities

Data Condensation

Data condensation in this study focused on key aspects related to the data obtained, namely the results of students' written test answers and the interviews conducted.

Data Display

Data presentation in this study involves presenting the results of the written test answers and interviews for each subject based on problem-solving indicators. The problem-solving indicators used are: (1) restating a concept; (2) classifying objects according to specific properties (in accordance with the concept); (3) using, applying, and selecting specific procedures or operations; (4) applying concepts or problem-solving algorithms.

a. Data Presentation: Understanding the Concept of RR in Restating a Concept

RR was able to understand and accurately restate the intent of the problem. In the interview, RR stated, "This equation must be proven so that the left side equals the right side." (RRT106). This can be seen in Figure 3 below.

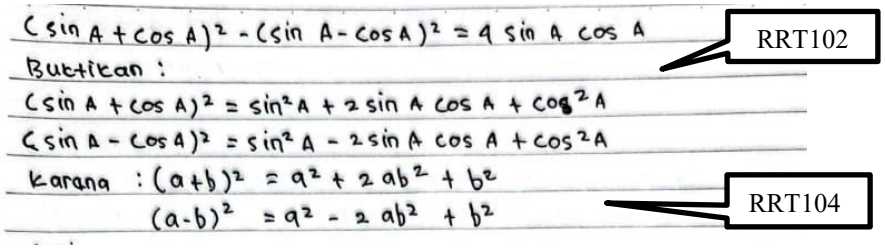

Figure 3. Analysis of Subject RR's Responses in Restating a Concept

This indicates that RR meets the indicator for restating concepts. The following interview excerpts are used to support the analysis results.

PNT101: In your opinion, what is being asked in that question?
RRT102: To prove that the left-hand side is equal to the right-hand side in the equation ((\sin A+\cos A)^2 - (\sin A-\cos A)^2 = 4\sin A\cos A).

PNT103: What concept or formula did you use?
RRT104: I used the formulas for the square of the sum and the square of the difference, namely ((a+b)^2=a^2+2ab+b^2) and ((a-b)^2=a^2-2ab+b^2).

Based on the written response and the interview results, the subject was able to restate the concepts used in solving the problem, namely the algebraic identities in the form of the quadratic sum and difference formulas. This was demonstrated through the writing of the formulas in the written response and the subject's explanation during the interview (RRT104), thus fulfilling the indicator for restating concepts.

b. Presentation of Data on RR's Conceptual Understanding in Classifying Objects According to Specific Properties (in Accordance with the Concept)

RR identified the problem as a quadratic algebraic expression that could be solved using the formulas ((a+b)²) and ((a-b)²). "Use the quadratic formulas, the ones for (a+b)² and (a-b)², because the pattern is similar." (RRT108). This can be seen in Figure 4 below.

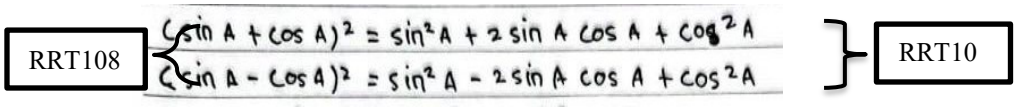

Figure 4. Analysis of responses regarding the use, application, and selection of specific procedures or operations

Thus, RR is able to classify objects based on appropriate properties and concepts. The following interview excerpts support the results of the analysis.

PNT105: Why use the formulas for the sum of squares and the difference of squares?
RRT106: Because ((\sin A + \cos A)^2) is the sum of squares, while ((\sin A - \cos A)^2) is the difference of squares.
PNT107: In that formula, which is considered (a) and which is (b)?
RRT108: I consider (\sin A) to be (a) and (\cos A) to be (b).

Based on the written answers and interview results, subject RR was able to classify algebraic expressions according to their properties by identifying ((\sin A + \cos A)^2) as the sum of squares and ((\sin A - cos A)^2) as the square of a difference, and to identify (\sin A) as (a) and (\cos A) as (b) (RRT106–RRT108). Thus, the indicator for classifying objects based on specific properties has been met.

c. Data Presentation on RR Conceptual Understanding in Using, Applying, and Selecting Specific Procedures or Operations

RR's written response regarding the use, application, and selection of specific procedures or operations in solving trigonometric identity problems, as shown in Figure 5.

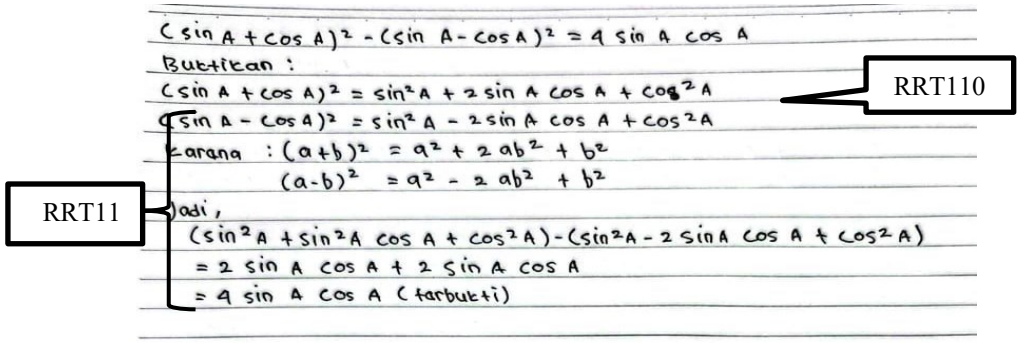

Figure 5. Analysis of subjects' responses regarding the use, application, and selection of specific procedures or operations

The following interview excerpts support the results of the analysis.

PNT109: After determining the formula, what was the first step you took?
RRT110: I expanded ((\sin A+\cos A)^2) and ((\sin A-\cos A)^2) using the formulas for the square of a sum and the square of a difference.
PNT111: Why did you choose that step?
RRT112: So that the left-hand side could be simplified to equal the right-hand side, making it suitable for the proof.

Based on the written answers and interview results, subject RR was able to select and use the appropriate procedure to complete the proof of the trigonometric identity. The subject began the solution by expanding both quadratic expressions using the appropriate formulas, then simplified them until the desired form was obtained. The subject's explanations during the interview (RRT110–RRT112) indicate that these procedures were consciously chosen to prove the equality of the two sides, thus fulfilling the indicators of using, applying, and selecting specific procedures or operations.

d. Presentation of Data on RR's Conceptual Understanding in Applying Concepts or Problem-Solving Algorithms

RR's written response regarding the use, application, and selection of specific procedures or operations in solving trigonometric identity problems, as shown in Figure 6.

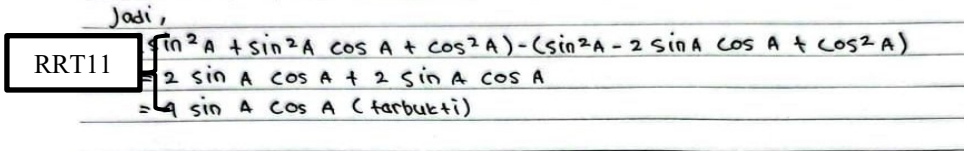

Figure 6. Analysis of subject RR's responses regarding the application of problem-solving concepts or algorithms

The following interview excerpt supports the results of the analysis.

PNT113: After factoring both expressions, how did you complete the proof?
RRT114: I subtracted the two factored expressions from each other, and then the terms (\sin^2A) and (\cos^2A) canceled each other out, leaving (4\sin A\cos A).
PNT115: How did you know your proof was correct?
RRT116: Because the simplified expression on the left-hand side is equal to the one on the right-hand side, namely (4\sin A\cos A).

Based on the written answers and the interview results, subject RR was able to apply problem-solving concepts and algorithms accurately. The subject subtracted the factored terms, eliminated the common terms, and obtained the final result (4\sin A\cos A). The explanations provided during the interview (RRT114–RRT116) indicate that the subject understands the rationale behind the proof, namely the equality between the left-hand side and the right-hand side. Thus, the indicator for applying problem-solving concepts or algorithms has been met.

Drawing Conclusions

Based on the results of the written test and interview, subject RR was able to meet all four indicators of conceptual understanding. The subject was able to restate the concepts by explaining the purpose of the problems and identifying the formulas for the square of the sum and the square of the difference that were used. The subject was also able to classify algebraic expressions by distinguishing between the sum of squares and the difference of squares and identifying (\sin A) as variable (a) and (\cos A) as variable (b). Additionally, the subject was able to select the appropriate procedure by factoring the quadratic expression before simplifying it. Furthermore, the subject is able to apply concepts and solution algorithms by subtracting the results of the expansion, eliminating like terms, until obtaining the final result (4\sin A\cos A), thereby correctly proving the trigonometric identity.

Analysis of Subject VS's Data in Solving Problems Based on the Indicator of Understanding Trigonometric Identity Concepts

Data Condensation

The data condensation performed in this study focused on key aspects related to the data obtained, namely the results of students' written test answers and the interview results.

Data Display

The data presented in this study consists of the results of written tests and interviews with each subject, based on indicators of problem-solving performance. The problem-solving indicators used are as follows: (1) restating a concept; (2) classifying objects according to specific characteristics (in accordance with the concept); (3) using, applying, and selecting specific procedures or operations; and (4) applying problem-solving concepts or algorithms.

a. Data Presentation: Conceptual Understanding vs. Restating a Concept

The written answer VS restates a concept in a trigonometric identity problem, as shown in Figure 7.

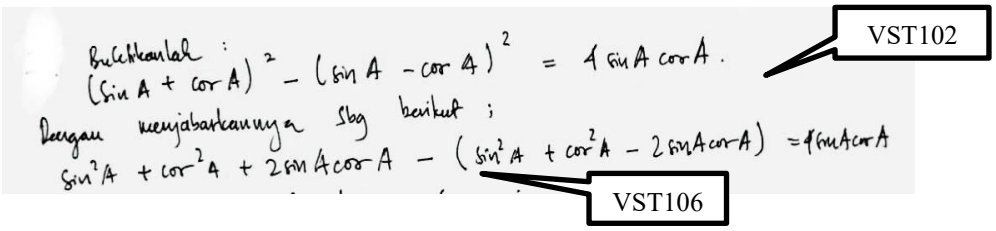

Figure 6. Analysis of Subject VS's responses in restating a concept

This indicates that VS meets the indicator for restating concepts. The following interview excerpt reinforces the analysis results.

PNT101: What is being asked in this problem?
VST102: To prove that the left-hand side is equal to the right-hand side in the equation ((\sin A+\cos A)^2 - (\sin A-\cos A)^2 = 4\sin A\cos A).
PNT103: What concept or formula did you use?
VST104: The formulas for the sum of squares and the difference of squares.
PNT105: What do the formulas look like?
VST106: ((a+b)^2=a^2+2ab+b^2) and ((a-b)^2=a^2-2ab+b^2).

Based on the written answers and interview results, subject VS was able to restate the concepts used in proving the trigonometric identities. Although the subject did not explicitly write out the formulas on the answer sheet, they directly and correctly applied the formulas for the sum of squares and difference of squares during the process of deriving the algebraic expressions. The explanations provided during the interview (VST104–VST106) further demonstrated that the subject understood the concepts used, thus fulfilling the indicator of concept restatement.

b. Presentation of Data on VS's Conceptual Understanding in Classifying Objects According to Specific Properties (in Accordance with the Concepts)

Written answer VS for classifying objects according to specific properties (in accordance with the concept) in a trigonometric identity problem.

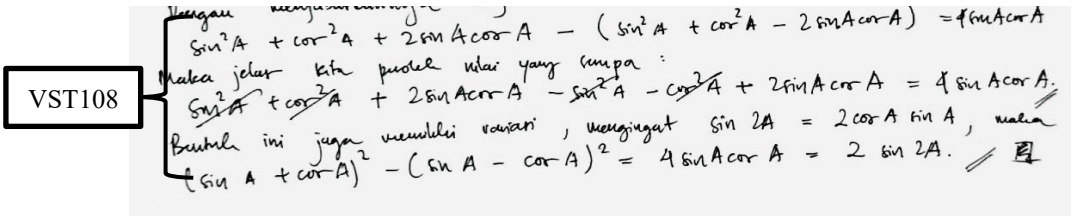

Figure 7. Analysis of the Subjects' Responses in Classifying Objects According to Specific Characteristics (in Accordance with Their Concepts)

c. Data Presentation: Conceptual Understanding vs. the Ability to Use, Apply, and Select Specific Procedures or Operations

Written answers regarding the use, application, and selection of specific procedures or operations in problems involving trigonometric identity equations, as shown in Figure 8.

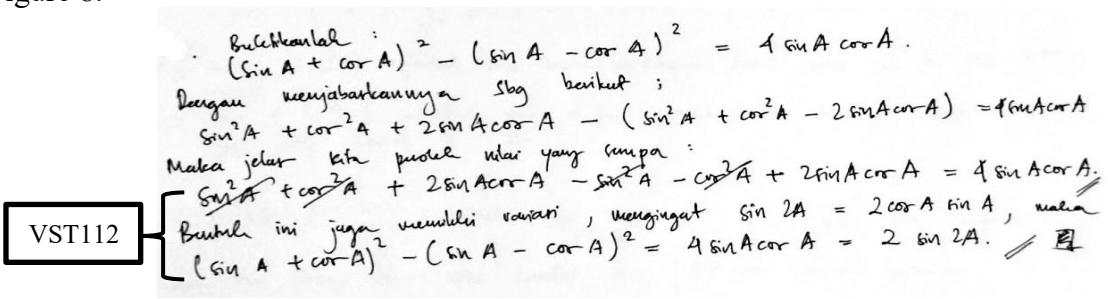

Figure 8. Analysis of Subjects' Responses Regarding the Use, Application, and Selection of Specific Procedures or Operations

The following interview excerpts support the results of the analysis.

PNT111: After factoring the quadratic expression, what is the next step?
VST112: I subtract the two results.
PNT113: Why did you choose that step?
VST114: Because the expression in the problem is the subtraction of two quadratic expressions, so after factoring, it can be simplified.

Based on the results of the written test and the interview, subject VS was able to use and select the appropriate procedure to solve the trigonometric identity. The subject expanded the expressions ((\sin A+\cos A)^2) and ((\sin A-\cos A)^2) using the appropriate formulas, then performed the subtraction operation on the results of those expansions. The subject's explanations during the interview (VST112–VST114) indicate that the selection of procedures was based on the form of the operations in the problem, thus fulfilling the indicators of using, applying, and selecting specific procedures.

d. Data Presentation: Conceptual Understanding vs. Applying Concepts or Problem-Solving Algorithms

Written answers regarding the use, application, and selection of specific procedures or operations in problems involving trigonometric identity equations, as shown in Figure 9.

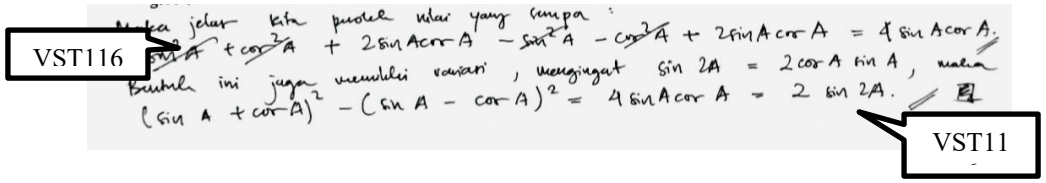

Figure 9. Analysis of Subjects' Responses in Applying Problem-Solving Concepts or Algorithms

The following interview excerpts reinforce the results of the analysis.

PNT115: Why was that term eliminated?
VST116: Because (\sin^2 A) in both terms has the same value, so their difference is zero.
VST117: What about (\cos^2 A)?
VST118: Same thing—since their values are the same, they cancel each other out.
VST119: Why didn't the term (2\sin A\cos A) cancel out?
VST120: Because they have opposite signs, so the result becomes (4\sin A\cos A).
PNT123: Why was (4\sin A\cos A) changed to (2\sin 2A)?
VST124: Because the double-angle formula is used (2\sin A\cos A=\sin 2A).
PNT125: How do you know the proof is correct?
VST126: Because the simplified left-hand side matches the required form, so both sides are equal.

Based on the results of the written test and interview, subject VS was able to accurately apply problem-solving concepts and algorithms. The subject performed simplification by eliminating like terms, retaining terms with different signs, and applying the double-angle identity to obtain the final form (2\sin 2A). The subject's explanations during the interview (VST116–VST126) demonstrated an understanding of each step in the solution and the rationale for using those concepts. Thus, the indicator of applying problem-solving concepts or algorithms has been met.

Drawing Conclusions

Based on the results of the written test and interview, subject VS was able to meet all four indicators of conceptual understanding. The subject was able to restate the concepts by stating and applying the quadratic formula for addition ((a+b)^2=a^2+2ab+b^2) and the quadratic formula for subtraction ((a-b)^2=a^2-2ab+b^2), even though the formulas were not written directly on the answer sheet. The subject was also able to classify algebraic expressions based on their sign properties, specifically by using the quadratic sum formula for expressions with a positive sign and the quadratic difference formula for expressions with a negative sign. In addition, the subject is able to select and use the appropriate procedure by factoring, eliminating like terms, and simplifying the result of the operation. The subject is also able to apply problem-solving concepts and algorithms through the use of the double-angle identity (2\sin A\cos A=\sin 2A) to obtain a final result that matches the form being proven.

Discussion

After identifying two research subjects male students with high mathematical ability (VS) and female students with high mathematical ability (RR) an analysis was conducted of their conceptual understanding profiles in solving trigonometric identity problems based on indicators of conceptual understanding. The results of the written test and interviews showed that both subjects had good conceptual understanding, but there were differences in the strategies and methods they used

to apply concepts during the problem-solving process. The discussion of each subject is presented as follows.

Conceptual Understanding Profile of a Female Student with High Mathematical Ability (RR)

The results of the written test and interview analysis indicate that the female subject with high mathematical ability (RR) met all the indicators of conceptual understanding in the trigonometric identities material. This finding is consistent with Rahman et al. (2022), who stated that high-ability female students demonstrate consistency in meeting the indicators of conceptual understanding. For the concept restatement indicator, RR was able to explain the purpose of proving trigonometric identities as well as write down and explain the sum-of-squares and difference-of-squares formulas used. For the object classification indicator, RR was able to identify algebraic expressions based on their properties and determine the role of each variable in the applied formula. Furthermore, RR was able to select the appropriate solution procedure by expanding quadratic expressions, performing subtraction, and systematically simplifying terms. For the "applying concepts" indicator, RR successfully applied algebraic operations and trigonometric identities to arrive at the correct proof results. These results indicate that RR possesses a strong conceptual understanding, as he is able to connect concepts, select appropriate procedures, and apply algorithms systematically. These findings also support Shadiq's (2009) view that the ability to restate concepts is a key indicator of mathematical conceptual understanding.

Conceptual Understanding Profile of a Male Student with High Mathematical Ability (VS)

The results of the written test and interview analysis show that the male subject with high mathematical ability (VS) met all indicators of conceptual understanding regarding trigonometric identities. VS was able to restate the concepts by explaining the purpose of proving the identities and the quadratic formulas used, even though he did not write them down explicitly on the answer sheet. This finding is consistent with Shadiq (2009), who states that the ability to restate concepts is one of the indicators of conceptual understanding. Regarding the indicator of classifying objects, VS was able to distinguish between the use of the quadratic addition and subtraction formulas based on the sign properties of the algebraic expressions. Furthermore, VS was able to select the appropriate solution procedure by expanding both quadratic forms, simplifying like terms, and performing subtraction according to the problem's structure. Regarding the "applying concepts" indicator, VS successfully applied trigonometric identities systematically to obtain the correct final result, namely (2\sin 2A). This result indicates that VS possesses a strong conceptual understanding, as they were able to connect concepts, select appropriate procedures, and apply algorithms correctly. These findings support Wathall's (2020) assertion that students with strong relational understanding are capable of meeting all indicators of mathematical conceptual understanding.

4. Conclusion

Based on the research findings and discussion, it can be concluded that both female students (RR) and male students (VS) with high mathematical ability met all indicators of conceptual understanding when solving trigonometric identity problems. Both groups were able to restate the concepts used, classify terms according to their trigonometric properties and forms, select the appropriate solution procedure, and systematically apply concepts or algorithms to arrive at the correct answer. However, there were differences in the solution strategies employed. RR tended to solve problems by grouping terms based on trigonometric forms, such as the square of a sine, the square of a cosine, and the product of a sine and a cosine, then solving them step by step according to the procedure. Meanwhile, VS placed greater emphasis on the simplification process by eliminating opposing terms and utilizing the grouping of like terms, thereby making the solution steps more efficient. These differences in strategy do not affect the final results, as both groups demonstrate a good understanding of the concepts and are able to solve the problems correctly. Thus, both female and male students with high mathematical ability demonstrate excellent mastery of trigonometric identity concepts, even though they use different problem-solving approaches.

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