Analysis of students' mathematical communication skills on the pythagoras theorem material in class viii of junior high school

Padilah Rahmah[1], Maydiyanti Putri[2], Reni Wahyuni[3*]
[1,2,3*]Mathematics Education, Universitas Islam Riau, Riau, Indonesia
[1]padilahrahmah@student.uir.ac.id; [2]maydiyantiputri@student.uir.ac.id; [3]reniwahyunifkipmat@edu.uir.ac.id

DOI: https://doi.org/10.31980/pme.v4i2.2908

Submission Track:
Received: 12-04-2025 | Final Revision: 18-05-2025 | Available Online: 30-06-2025

How to Cite:
Rahmah, P., Putri, M., & Wahyuni, R. (2025). Analysis of students' mathematical communication skills on the pythagoras theorem material in class viii of junior high school. *Jurnal Inovasi Pembelajaran Matematika: PowerMathEdu (PME), 4*(2), 301-318.

Abstract
This study aims to evaluate the mathematical communication skills of eighth-grade junior high school students on the topic of the Pythagorean Theorem. Mathematical communication is essential as it reflects conceptual understanding, procedural skills, and the ability to clearly express ideas both verbally and in writing. A descriptive qualitative approach was used, involving 23 students as participants. Data were collected through essay tests based on NCTM indicators and supported by interviews. The results showed that 73.91% of students had moderate communication skills, 13.04% were in the high category, and some were able to express mathematical ideas and use symbols accurately. These findings highlight the need for more varied and focused instructional strategies, particularly to improve calculation accuracy, mathematical language use, and visual representation of concepts.
Keywords: Mathematical Communication; Pythagorean Theorem; Mathematics Learning; Student Ability; Junior High School

Abstrak
Penelitian ini bertujuan mengevaluasi kemampuan komunikasi matematis siswa kelas VIII SMP pada materi teorema pythagoras. Komunikasi matematis penting karena mencerminkan pemahaman konsep, keterampilan prosedural, dan kemampuan menyampaikan ide secara jelas, baik lisan maupun tulisan. Penelitian ini menggunakan pendekatan kualitatif dengan melibatkan 23 siswa. Data dikumpulkan melalui tes esai berdasarkan indikator NCTM dan wawancara sebagai pelengkap. Hasil menunjukkan 73,91% siswa memiliki kemampuan sedang, 13,04% tinggi, dan sebagian mampu menyampaikan ide serta simbol matematika dengan benar. Temuan ini menunjukkan perlunya strategi pembelajaran yang lebih variatif dan terarah, terutama untuk meningkatkan akurasi perhitungan, penggunaan bahasa matematika, dan representasi visual konsep.
Kata Kunci: Komunikasi matematis; Teorema Pythagoras; Pembelajaran Matematika; Kemampuan Siswa; SMP

Introduction

Math is language, so it is very important to communicate both orally and in writing so that others can understand what is being conveyed. Mathematics is a very powerful, thorough, and non-confusing communication tool (Gunawan et al., 2024). According to Cockroft (in Aminah et al., 2018) it can be believed that various views on the importance of mathematics are rooted in the fact that mathematics provides an efficient, concise, and non-dualistic means of communication. According to Baroody (Nugraha & Pujiastuti, 2019), communication plays an important role in mathematics learning for two reasons. First, mathematics serves as a means of expressing ideas in an efficient and clear way, and has universal properties that allow its comprehension beyond the boundaries of language. Second, mathematics learning activities are a social process that involves interaction between teachers and students, so there is a need for an exchange of ideas and thoughts. This study aims to evaluate students' mathematical communication skills in mathematics education courses, both in general, based on assessment categories, and from correct answers in exams.

The National Council of Teachers of Mathematics (NCTM) emphasizes that mathematical communication is one of the most important skills in mathematics learning and teaching. In the document (NCTM, 2000) it is explained that the indicators of these abilities include: 1) students' skills in expressing and explaining mathematical ideas orally and in writing; 2) the ability to decipher mathematical designs through visual media such as pictures, graphs, or diagrams; and 3) accuracy in using symbols and mathematical language to convey various concepts. Meanwhile, according to Suliyani, Amrullah, and Kurniati (2004), mathematical communication skills themselves have an important role in daily life, because basically communication is a means to convey messages, ideas, and ideas to others (Nugraha & Pujiastuti, 2019; Ikhsan & Afriansyah, 2023) .

Mathematical communication in written form can be realized through the use of language, pictures, tables, or diagrams that represent the student's thought process. In addition, this communication can also be in the form of a description of problem-solving steps or a mathematical proof that shows students' ability to organize and connect various concepts to solve a problem (Sudrajat, 2022; Sulastri & Sofyan, 2022).

Based on the above background, this study aims to evaluate the mathematical communication skills of grade VIII junior high school students on the Pythagorean theorem material. The results of this study are expected to provide an overview of the level of students' mathematical communication skills and the factors that affect them, so that they can be used as a basis for developing more effective learning strategies to improve these abilities.

Method

This type of research is phenomenology research, with a qualitative approach. The research was conducted at SMPN in Siak Hulu. The population in this study is grade VIII students, with a sample of 23 students.

The data collection techniques used in this study include a written test in the form of six essay questions related to the Pythagorean Theorem material, where each question is designed to measure one indicator of mathematical communication ability. In addition, data collection is also carried out through interviews.

The mathematics communication indicators used in this learning refer to the standards of the National Council of Teachers of Mathematics (NCTM) which include: (1) students' skills in expressing and explaining mathematical ideas orally and in writing; (2) the ability to decipher mathematical designs through visual media such as drawings, graphs, or diagrams; and (3) accuracy in using symbols and mathematical language to convey various concepts. The data analysis technique in this learning is carried out through a number of steps, namely data collection, data presentation, data reduction, and conclusion drawn. Each stage is carried out in a structured manner to gain a comprehensive understanding of the data and produce findings that are in accordance with the research objectives. Based on the test results, students' mathematical communication skills are categorized into 3, namely high, medium, and low categories. The category guidelines are grouped based on criteria according to Arikunto (in Sintia, 2022). which refers to the percentage of scores that students get from the overall ability of the indicator.

Table 1. Criteria for mathematical communication skills

Category	Value Criteria
Tall	$x \geq \tilde{x} + s$
Now	$\tilde{x} - s \leq x < \tilde{x} + s$
Low	$x < \tilde{x} - s$

Information:
$x = nilai\ siswa$
$\tilde{x} = nilai\ rata - rata\ siswa$
$s = standar\ deviasi$

Result

In this study, the education participants who were made subjects would be given a test. The research refers to the indicator of mathematical communication ability to facilitate the implementation process. To find out the level of students' ability to solve problems, an evaluation of learning outcomes is carried out. The data on student test results were analyzed based on standardized scoring guidelines for mathematical communication skills. Furthermore, the mathematical communication skills of Class VIII students of State Junior

High School in Siak Hulu are presented in the form of descriptive statistics in the following table.

Table 2. Results of students' mathematical communication ability test

Number of Students	Maximum Value	Minimum Score	Average	Standard Deviation
23	85	10	45.54	17.52

Based on Table 2, it can be seen that the highest score obtained by students is 85, while the lowest score is 10. The average student score was 45.54, which shows that, in general, students' mathematical communication skills are still in the moderate or not optimal category. In addition, the standard deviation of 17.52 indicates that there is a fairly large distribution of scores between students, which means that there is a significant difference in ability between individuals. This shows that while there are some students who show good skills, others still need additional guidance to improve their competence in mathematical communication.

Table 3. Percentage of mathematical communication ability criteria

Category	Value Criteria	Sum	Percentage
Tall	$x \geq 63{,}06$	3	13,04%
Now	$28{,}02 \leq x < 63{,}06$	17	73,91%
Low	$x < 28{,}02$	3	13,04%
Total	63,06	23	100%

Table 3 shows the distribution of students' mathematical communication skills based on three assessment categories, namely high, medium, and low. Of the total 23 students studied, 3 students, or 13.04%, were classified in the high category with a score of ≥ 63.06. Meanwhile, most of the students, namely 17 people or 73.91%, are included in the medium category with a score range between 28.02 to less than 63.06. The rest, as many as 3 students or 13.04%, are in the low category with a score below 28.02. These results show that the majority of students have a moderate level of mathematical communication skills, while students with very high and very low abilities are only a few. These findings can be used as a basis for improving learning strategies so that more students reach the high category and reduce the number of students who are in the low category. The following are the results of the analysis to answer students' mathematical communication skills using the triangulation technique, which can be seen in Table 5.

Table 4. Participant code

Categories Math Connection Ability	Student Code
Low	CN
Medium	YS
Tall	NM

Table 5. Test and Interview Data Triangulation Results

No.	Student Code	Indicators	Written Test Results	Interview Results
1	NM	students' skills in expressing and explaining mathematical ideas orally and in writing	Even though the student answered question number 1 correctly, he did not include a formula in the solution. In question number 2, the students have given the correct answer, but have not included a formula for the solution	Because they feel that they already understand the material, students immediately write down the answers and their grades without including completion steps. Because students feel that they already understand and just enter the score and answer the question
		Ability to describe mathematical designs through visual media such as drawings, graphs, or diagrams	In question number 3, students answered correctly, but the 'questioning' part has not been fully conveyed In question number 4, students answered the questions correctly and completely	Students forget to put it Students already understand and have studied
		precision in the use of symbols and mathematical language to convey various designs.	In question number 5, students answered the questions correctly and appropriately In question number 6, students answered the question incorrectly	Students already understand and have studied Students feel that the answer is correct
2	YS	students' skills in expressing and explaining mathematical ideas orally and in writing	In question number 1, students answered the question correctly only in the part that was known and asked Incomplete In question number 2, students answered the question correctly only in the part that was known and asked Incomplete	Students forget to make it because they feel no influence Students forget to make it because they feel no influence
		Ability to describe mathematical designs through visual media	In question number 3, students answered the	Students already understand and have studied

No.	Student Code	Indicators	Written Test Results	Interview Results
		such as drawings, graphs, or diagrams	questions correctly and completely In question number 4, students answered the questions correctly and completely	Students already understand and have studied
		precision in the use of symbols and mathematical language to convey various designs.	In question number 5, students did not answer the question In question number 6, students did not answer the questions	Students do not understand because Students do not understand because
3.	CN	students' skills in expressing and explaining mathematical ideas in a way that	In question number 1, the student answered incorrectly In question number 2, students did not answer the question	Students don't know the answer Students Don't understand and don't know how to solve it
		Ability to describe mathematical designs through visual media such as drawings, graphs, or diagrams	In question number 3, students answered the question incorrectly In question number 4, students did not answer the questions	Students don't know the answer Students Don't understand
		precision in the use of symbols and mathematical language to convey various designs.	In question number 5, students did not answer the question In question number 6, students did not answer the questions	Students Don't Understand At All Students Don't Understand At All

Discussion

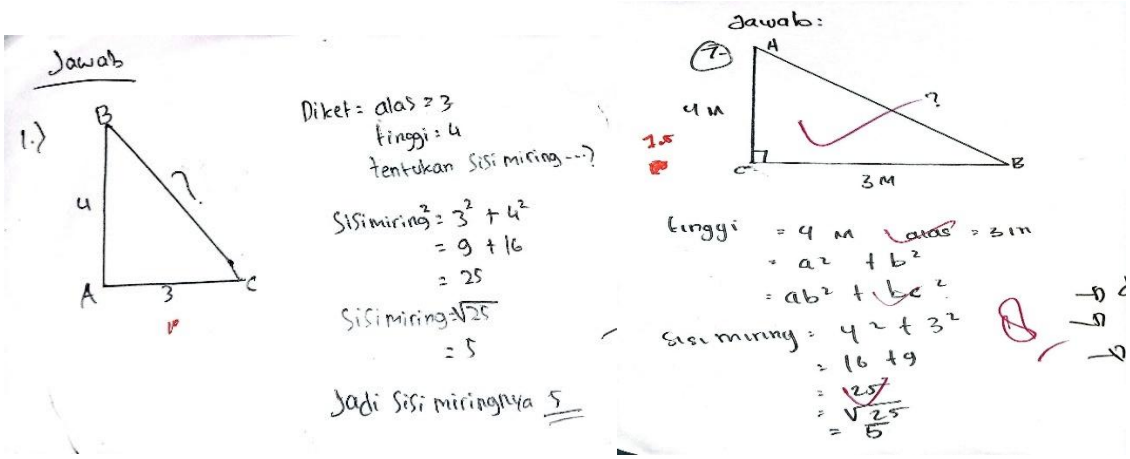
This study describes the extent to which students are able to build students' mathematical communication when working on problems related to the *material of the Pythagorean Theorem*. The measuring tool used is in the form of six written questions. The assessment of students' mathematical communication skills is based on three main indicator points described in detail in the discussion, namely:

1. Students' skills in expressing and explaining mathematical ideas orally and in writing. Questions 1&2

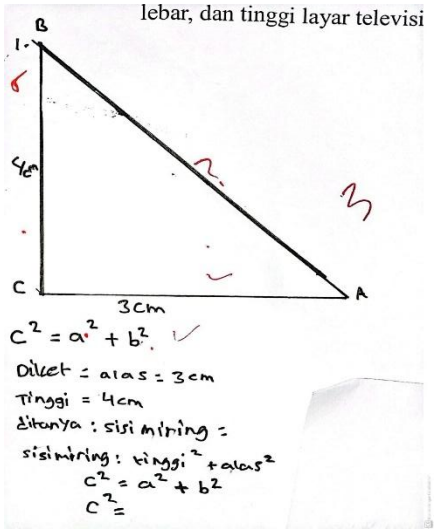
Soal 1

Sebuah tangga bersandar pada dinding rumah sehingga ujung atas tangga berada 4 meter di atas tanah. Jika kaki tangga berjarak 3 meter dari dinding maka tentukan panjang tangga tersebut! Tuliskan dengan rinci bagaimana kamu menemukan jawabannya!

Figure 1. Question number 1



(a) NM (b) YS



(c) CN

Figure 2. Work results of number 1

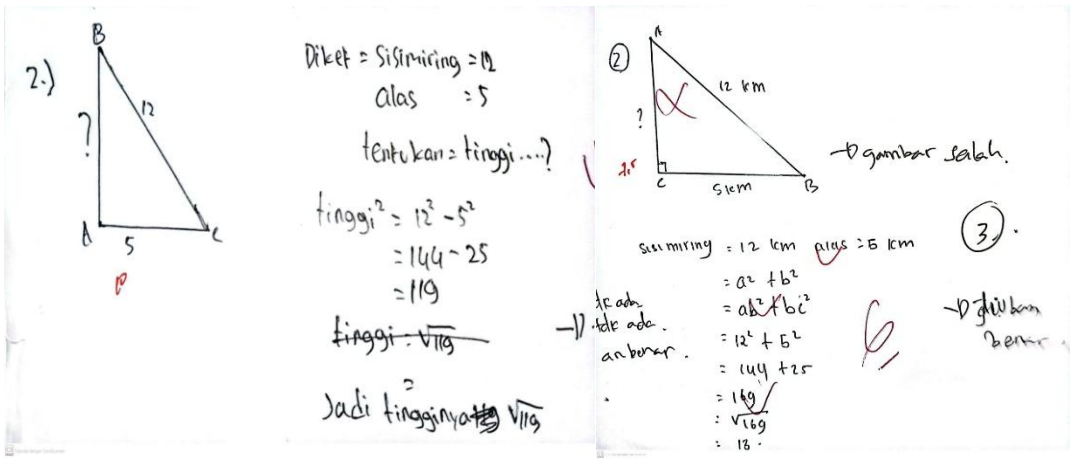
Based on Figure 2, the work of NM students shows a good understanding. He described a triangle and counted it. Then it was concluded that the length of the stairs was 5 meters. Based on the interview, NM admitted that he immediately wrote the final result without steps because he felt that he had understood the material well. This is in line with the findings $3^2 + 4^2 = 25$Yuliana et al., (2022) which states that a number of students with high abilities tend to go through a formal process because they feel that they have understood the material, so that the potential of mathematical communication has not

been sufficiently explored. YS students also show good understanding. He drew triangles, wrote down known information, and used the Pythagorean theorem correctly. YS answers are complete, structured, and demonstrate good mathematical communication skills. This is in accordance with research Alfi Rahmawati, Attin Warmi, (2023) which states that students with high abilities are usually able to solve problems systematically, following the stages of solving problems. Meanwhile, CN students have not completed the questions completely. He only wrote the *Known*, *Asked*, and formulas without doing calculations. This shows that CN understands the initial part of the solution, but still has difficulty in applying the formula procedurally until it gets a final answer. This phenomenon is in line with the findings of the Habibullah & Hartono, (2019), which analyzes the difficulties of junior high school students in solving Pythagorean Theorem problems. They found that the biggest obstacle for students lies in the Solution implementation stage and answer checking; Students often stop after writing down formulas without proceeding to the counting stage.

Soal 2

Leehan dan Woonhak berjalan dari titik yang sama. Leehan berjalan ke arah timur sejauh 5 km, kemudian belok ke utara sejauh 12 km. Woonhak berjalan langsung menuju titik akhir Leehan berada. Hitunglah jarak yang di tempuh Woonhak?

Figure 3. Question number 2



(a) NM (b) YS

(c) CN

Figure 4. Work results of number 2

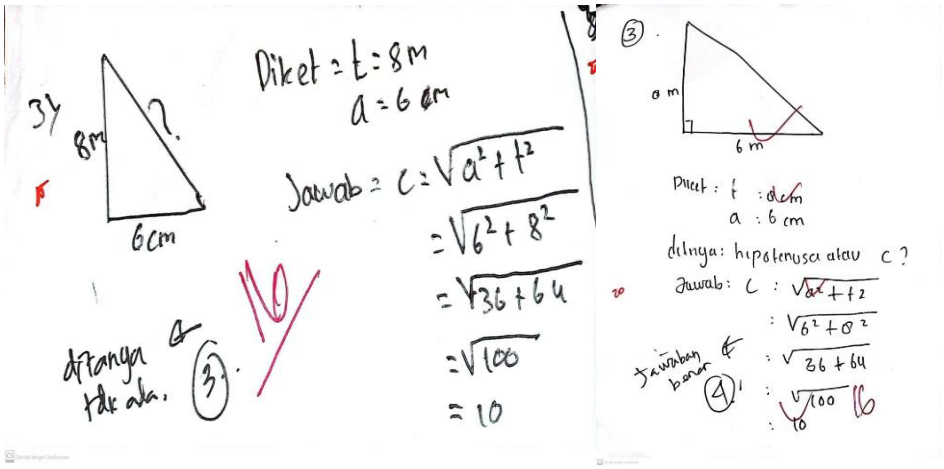
Based on Figure 4, the work of NM students shows a good understanding. He is able to identify right triangles, write down known information, and perform calculations using the correct formula. Although the final result is not simplified, the steps are systematic and precise. Drawing from the interview results, NM admitted that he had understood the questions and immediately worked on them without hesitation. These findings are in line with research $12^2 - 5^2 = 119$.Alfi Rahmawati, Attin Warmi, (2023) , which states that students with high abilities are able to solve Pythagorean problems, even though they sometimes lack the seriousness of reading the problems comprehensively. On the other hand, YS students also showed quite a good understanding. It presents information about the problem, describes triangles, and calculates the slant with proper usage, which results in km. However, there are small calculation discrepancies in the drawings that do not affect the final calculation result. On the other hand, CN students equally did not work on the problem and left the sheet blank, which showed that they did not understand the initial method of solving. This is in accordance with the results of the research $5^2 + 12^2 = 169\sqrt{169} = 13$(Indrawati et al., 2024) which indicates that students are of low difficulty at the "plan implementation" stage in the problem solving of the Pythagorean theorem. This is also supported by the findings Yuliana et al., (2022) which identifies types of student mistakes such as not being able to write down complete information, difficulty strategizing, and making mistakes in rank or square root operations. Based on the results of the interview, students do not understand how to solve it.

2. The ability to describe mathematical concepts through visual media such as pictures, graphs, or diagrams. Questions 3 & 4

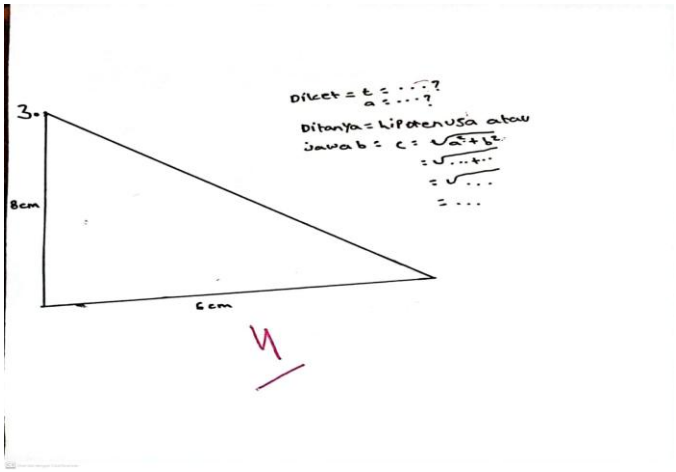
Soal 3

Sebuah tiang listrik setinggi 8 meter tumbang akibat angin kencang. Ujung atas tiang menyentuh tanah pada jarak 6 meter dari pangkal tiang. Gambarlah sketsa situasi tersebut dan berapakah hipotenusa nya?

Figure 5. Question number 3



(a) NM (b) YS



(c) CN

Figure 6. Work results of number 3

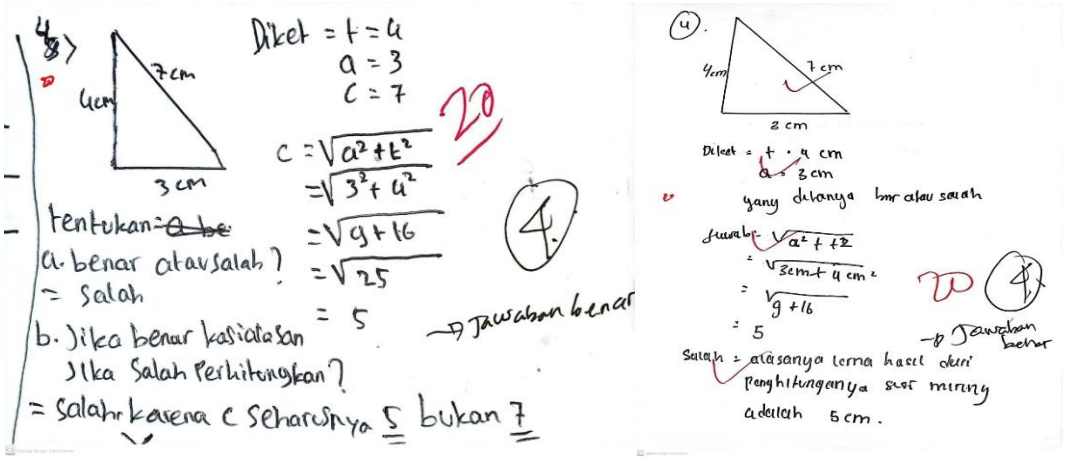
Based on Figure 6, the work of NM students shows a good understanding of the material. He drew a right triangle according to the context, wrote down the length information of its sides with the right angles, and correctly calculated the length of the oblique sides using the Pythagorean theorem, i.e. . These steps are systematic, neat, and produce the correct answers. This is in line with the findings $\sqrt{8^2}+ 6^2 = \sqrt{100} = 10$Indrawati et al., (2024) Students with mid-to-upper abilities are usually able to carry out the design of the solution in an appropriate manner although sometimes they do not do in-depth reflection or final examination. These findings are also supported by research Suryani et al., (2020) who found that moderately capable students tended to solve

problems by understanding problems, designing, and implementing solutions, but often did not double-check the results obtained. YS students also understand the design quite well. It includes a triangle drawing and the necessary information, as well as performing the calculations correctly. The result was suitable, namely, the slope was 20 meters long. However, the sketches made were disproportionate because the height of the pillars, which should have been greater than the base, was not accurately drawn, although this error did not affect the calculation results. These findings are in line with Tchonang's research, Tchonang Youkap & Rowland Baidoo, which suggests that inaccuracies in graphical representations—such as images that don't reflect proportion—can reflect imprecise conceptual understanding even if the mathematical reasoning process is correct and logical. Meanwhile, CN students simply draw triangles and write down known monetary data without continuing the calculation process. Based on the results of the interviews, CN students did not know the answers and did not understand the material, so further guidance was needed. This is in line with the findings of Putri Utami & Setiyawati, which states that "students' mathematical problem-solving skills still tend to be low... students do not achieve all the indicators of problem solving", especially in the implementation and solution checking stages.

Soal 4

Diketahui segitiga siku-siku dengan sisi-sisi 3 cm, 4 cm dan seorang siswa menyatakan sisi miringnya pasti 7 cm. Apakah kamu setujui dengan pendapat siswa tersebut? Jika tidak setuju, nyatakan alasanmu dan perhitungan yang benar!

Figure 7. Question number 4



(a) NM (b) YS

(c) CN

Figure 8. Work results of number 4

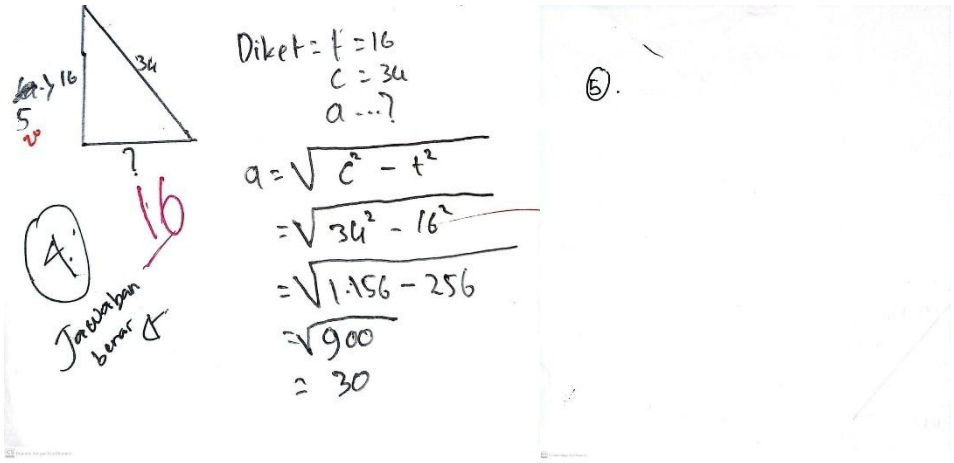
Based on Figure 8, the work of NM students shows excellent understanding. He explained the steps in sequence, starting from writing down information, using the Pythagorean theorem, and concluded that the oblique side of the triangle was not 7 cm, but 5 cm. NM also stated unequivocally that he did not agree with the students' opinion that the slanted side was 7 cm. The explanation and calculation are complete and accurate. This is in line with findings in a study by $\sqrt{3^2 + 4^2} = \sqrt{25} = 5$Klang et al., (2021) which shows that high-achieving students not only understand and design solutions correctly, but also consistently complete the process of reflection or verification of calculation results, as seen in NM profiles that consciously check and refute incorrect answers. YS students also showed a pretty good understanding. He described a triangle with its exact sides labeled, performed the correct calculation using the Pythagorean theorem, and concluded that the slope of the sides was 5 cm instead of 7 cm. However, the explanation is a little less systematic compared to NM, although the final result is still correct. This is in line with the findings Yuliyanti L & Tonra, (2021) that most students can use formulas appropriately, some still have difficulty in conveying sequential reasoning and conceptual visualization. Meanwhile, CN students did not work on the questions, so the answers were empty. Based on the results of the interview, students do not understand well, so they need further guidance. This is in accordance with research Wulandari & Riajanto, (2020) which shows that the greatest difficulties of junior high school students in the Pythagorean theorem occur in the "implementing", "planning" (54.4%) and "reflecting" (76.7%) stages. Without strategies and guidance, students as CNs tend to quit before reaching completion.

3. Precision in the use of symbols and mathematical language to convey various concepts. Questions 5&6

Soal 5

Suatu segitiga siku-siku memiliki panjang hipotenusa 34 cm dan salah satu sisi siku-siku adalah 16 cm. panjang siku-siku lainnya adalah…

Figure 9. Question number 5



(a) NM (b) YS

(c) CN

Figure 10. Work results of number 5

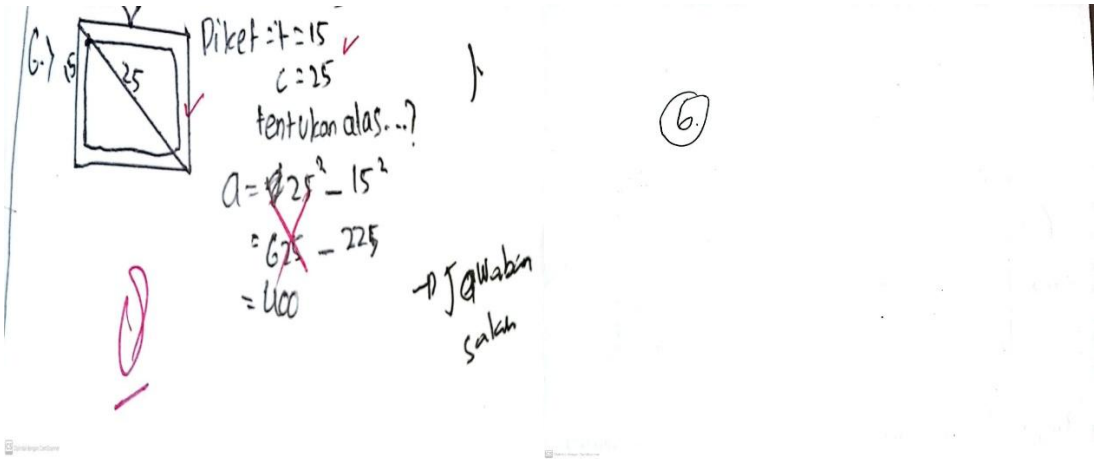
Based on Figure 10, the work of NM students shows a good understanding of the draft Pythagorean theorem. NM writes down information that is clearly known, the process of work is carried out systematically, and the final result is correct. This is in line with the findings Taamneh et al., (2024) In their study of X-grade students who used the Polya problem-solving approach to the Pythagorean Theorem, they found that students who were able to follow Polya's steps sequentially tended to produce accurate answers and fewer systematic errors. In addition, NM also includes a triangle image as visual support, as well as answers that are marked correct. demonstrate conceptual and procedural mastery, in accordance with the findings Resliana et al., (2020) which states that students who have a mature understanding of concepts are generally able to model problems and execute procedures appropriately. On the other hand, YS students do not

provide any answers or solutions. The same thing can also be seen in the CN student's answer, where he did not write down the condition of the answer. This shows that CN tends not to master the basic draft or feel unsure of themselves when answering questions. Based on the results of the interview, he did not understand the material so he needed further assistance to understand and apply the Pythagorean theorem. This is in line with the findings of the study (2024), which shows that "math anxiety and self-confidence influenced geometry problem-solving significantly", and that students with high anxiety or low confidence tend to quit before entering the solution implementation stage. In other words, the condition of YS and CN—who did not continue to solve problems due to uncertainty or lack of understanding is in line with the results of this research.

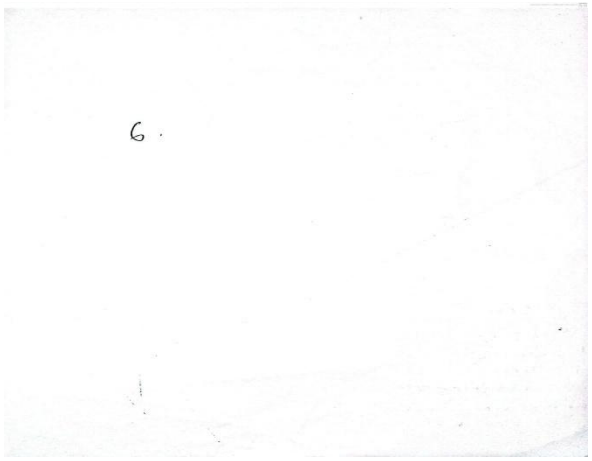
Soal 5

Suatu segitiga siku-siku memiliki panjang hipotenusa 34 cm dan salah satu sisi siku-siku adalah 16 cm. panjang siku-siku lainnya adalah…

Figure 11. Question number 6



(a) NM (b) YS



(c) CN

Figure 12. Work results of number 5

Based on Figure 12, NM students attempt to solve problems using the Pythagorean theorem. NM has written down the known information and the correct formula and described a rectangle with a triangle in it as a reference for calculation. However, there is an error in calculating squares. As a result, the final result of the calculation becomes incorrect. This is in line with the findings Rahmawaty & Nurmeidina, (2023) in the journal EMTEKA, which shows that most of the students' errors in the material of the Pythagorean Theorem occur due to inaccurate arithmetic calculations, even though the concepts and representations of the problem are well understood. However, NM shows an understanding of the basic concepts used, but it is necessary to be more careful in performing numerical calculations. Drawing from the interview result, NM students felt that the answer they made was correct. These findings are in line with research by Yadrika et al. (2019), which found that about 11–22% of students' errors on Pythagorean material were caused by "operational errors" or calculation errors, even though they understood the concepts and procedures of the basic material. This shows that the development of numerical accuracy needs to be improved, even though the understanding of the concept is good. In contrast, YS students did not give the same answers as CN students did not give answers. From the interview, it was known that CN did not understand the material, and YS also did not solve the problem because. This condition is in line with research by Pangestu & Kadarisma (2021),who found that some students stopped at the procedural stage or "carried out the plan", because they did not understand the formula enough or felt unable to continue the calculation process. In the study, it was stated that this type of obstacle arises when students are not able to translate formulas into systems and stop the steps before reaching the final result.

Conclusion

Based on the results of the research, it can be concluded that the mathematical communication skills of grade VIII junior high school students in the Pythagorean Theorem material are generally in the medium category. Of the 23 students studied, the majority of students (73.91%) were in the medium category, while 13.04% of students were in the high and low categories, respectively. The results of the analysis showed that a number of students as NM had a fairly good understanding of concepts and procedures in solving problems, although there were errors in technical aspects such as quadratic calculation and the use of mathematical symbols. Students as YS show good understanding, but are not consistent in delivering explanations or completeness of information in answering. On the other hand, students as CN show great obstacles in understanding and solving problems, not even being able to start work due to lack of mastery of basic drafts. The difficulties experienced by students, especially at the stage of "implementing" the plan, he

emphasized. The need for a learning strategy that emphasizes the strengthening of basic concepts, mathematical communication exercises in writing and visually, and intensive assistance for students who experience difficulties. The results of this research can be the basis for developing more effective learning methods to improve students' mathematical communication skills in the future.

Conflict of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

Reference

Aminah, S., Wijaya, T. T., & Yuspriyati, D. (2018). Baroody (Hendriana, Soemarmo, 2014) with the rationale a) mathematics is the essential language of information that is conveyed can be known and understood by others. Such as communication which is powerful, concise, and unambiguous.' Pernyat. *Journal of Scholars: Journal of Mathematics Education*, *1*(1), 15–22.

Gunawan, G., Ferdianto, F., Untarti, R., & Akhsani, L. (2024). Student Profile of Mathematical Communication Process of Prospective Mathematics Teachers Reviewed from Self-Confidence. *Mosharafa: Jurnal Pendidikan Matematika*, *13*(4), 1019-1034. https://doi.org/10.31980/mosharafa.v13i4.1958

Habibullah, & Hartono. (2019). An Analysis of Student Difficulties in Solving the Word Problem. *Journal of Physics: Conference Series*, *1320*(1). https://doi.org/10.1088/1742-6596/1320/1/012073

Ikhsan, D. M., & Afriansyah, E. A. (2023). Kemampuan Komunikasi Matematis Siswa SMP Pada Materi Himpunan. *Journal of Authentic Research on Mathematics Education (JARME)*, *5*(2), 203-214.

Indrawati, N., Nuramilan, N., & Amin, N. (2024). Analysis of Students' Difficulties in Solving Pythagorean Theorem Problems. *Cognitive: HOTS Research Journal of Mathematics Education*, *4*(1), 640–649. https://doi.org/10.51574/kognitif.v4i1.1421

Klang, N., Karlsson, N., Kilborn, W., Eriksson, P., & Karlberg, M. (2021). Mathematical Problem-Solving Through Cooperative Learning—The Importance of Peer Acceptance and Friendships. *Frontiers in Education*, *6*(August), 1–10. https://doi.org/10.3389/feduc.2021.710296

Nugraha, T. H., & Pujiastuti, H. (2019). Analysis of students' mathematical communication skills based on gender differences. *Edumatica: Journal of Mathematics Education*, *9*(1), 1–7. https://doi.org/10.22437/edumatica.v9i1.5880

Pangestu, D. A., & Kadarisma, G. (2021). Analysis of Junior High School Students' Mistakes in Solving Pythagorean Theorem Material. *Journal of Innovative Mathematical Learning*, *4*(6), 1497–1508. https://doi.org/10.22460/jpmi.v4i6.1497-1508

Putri Utami, D. S., & Setiyawati, E. (2022). Students' Mathematical Problem Solving Ability in Elementary School. *Open Academy*, *7*, 1–11. https://doi.org/10.21070/acopen.7.2022.4064

Rahmawati, A., & Warmi, A. (2023). Analysis of Mathematical Problem-Solving Abilities of Junior High School Students on Pythagorean Theorem Material. *Journal of Education and Teaching Innovation (JIPP)*, *2*(2), 1–6. https://doi.org/10.31571/jipp.v2i2.6130

Rahmawaty, A., & Nurmeidina, R. (2023). Analysis of students' mistakes in solving daily math test problems in phytagoras theorem material in the New Normal period. *EMTEKA: Journal of Mathematics Education*, *4*(1), 126–140.

Resliana, E. D., Nurmeidina, R., Mathematics, P., & Teacher, F. (2020). Understanding the Concept of the Phytagoras Theorem. *National Conference on Education 1*, 18–23.

Sudrajat, S. (2022). Analysis of Mathematical Communication Skills of Junior High School Students in Grade VIII in Solving Pythagorean Theorem Problems. *Lebesgue Journal: Scientific Journal of Mathematics, Mathematics and Statistics Education*, *3*(1), 186–199. https://doi.org/10.46306/lb.v3i1.112

Sulastri, E., & Sofyan, D. (2022). Kemampuan komunikasi matematis ditinjau dari self regulated learning pada materi sistem persamaan linear dua variabel. *Plusminus: Jurnal Pendidikan Matematika*, *2*(2), 289-302. https://doi.org/10.31980/plusminus.v2i2.1105

Suryani, I., Maidiyah, E., Salasi, & Mardhiah, M. Z. (2020). Students' mathematics problem-solving skills through the application of Problem-Based Learning model. *Journal of Physics: Conference Series*, *1460*(1). https://doi.org/10.1088/1742-6596/1460/1/012029

Taamneh, M. A., Díez-Palomar, J., & Mallart-Solaz, A. (2024). Examining tenth-grade students' errors in applying Polya's problem-solving approach to Pythagorean theorem. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(12). https://doi.org/10.29333/ejmste/15707

Tchonang Youkap, P., & Rowland Baidoo, S. (2024). Students' understanding of geometric figures in the process of constructing a conjecture at the secondary school. *Asian Journal for Mathematics Education*, *3*(4), 449–466. https://doi.org/10.1177/27527263241301268

Wahyuni, R., Juniati, D., & Wijayanti, P. (2024). How do Math Anxiety and Self-Confidence Affect Mathematical Problem Solving? *TEM Journal*, *13*(1), 550–560. https://doi.org/10.18421/TEM131-58

Wulandari, L., & Riajanto, M. L. E. J. (2020). Analysis of Junior High School Students' Difficulties in Solving Pythagorean Theorem Material Problems. *Journal of Mathematics Learning Education and Innovation Research (JRPIPM)*, *3*(2), 61. https://doi.org/10.26740/jrpipm.v3n2.p61-67

Yadrika, G., Amelia, S., & Roza, Y. (2019). Analysis of Junior High School Students' Mistakes in Solving Problems on Pythagorean Theorem and Circle Material. *JPPM (Journal of Mathematics Research and Learning)*, *12*(2), 195–212.

Yuliana, Y., Rahayu, R. R., & Firmansah, F. (2022). Student Mistakes in Solving Mathematical Problems on the Pythagorean Theorem. *Educational: Journal of Educational Sciences*, 4(4), 5532–5543. https://doi.org/10.31004/edukatif.v4i4.3294

Yuliyanti L, R. I., & Tonra, W. S. (2021). Analysis of Mathematical Concepts Misunderstanding of Junior High School Students on Pythagorean Theorem Material. *Delta-Pi: Journal of Mathematics and Mathematics Education*, *10*(2), 192. https://doi.org/10.33387/dpi.v10i2.3283