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THE PROFILE OF SECONDARY SCHOOL STUDENTS' WRITTEN MATHEMATICAL COMMUNICATION THROUGH PROBLEM SOLVING ASSESSMENT VIEWED FROM DIFFERENCES IN MATHEMATICAL ABILITY

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ABSTRACT

The aim of this study is to examine problem-solving assessments to measure the profile of students' written mathematical communication skills across low, medium, and high ability levels. The problem-solving assessment used includes a problem-solving test and an interview guide. This study is descriptive research with a qualitative approach. The research subjects consist of three students: one with low mathematical ability, one with medium mathematical ability, and one with high mathematical ability. High-ability students meet four indicators of written mathematical communication skills, which include writing down the known information and questions from the given problem and sketching a diagram, understanding mathematical ideas in planning and formulating rules or presenting formulas, interpreting information in carrying out the problem-solving plan, and reviewing/checking the correctness of the answers/conclusions. Medium-ability students meet one indicator of written mathematical communication skills, which is understanding mathematical ideas to plan and formulate rules or present formulas. Low-ability students do not meet any of the indicators of written mathematical communication skills.

Keywords : Assessment, Problem Solving, Written Mathematical Communication, Mathematical Ability

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PRELIMINARY

Mathematical communication skills are indeed pivotal in fostering higher-order thinking skills, including reasoning, decision-making, and critical analysis. These skills enable students to engage deeply with mathematical content, leading them to construct, analyze, and evaluate arguments. As students work to communicate their reasoning clearly, they develop the capacity to make informed decisions and justify their solutions (NCTM, 2000). Research on mathematical communication skills is important because effective communication in mathematics can strengthen conceptual understanding, enhance critical thinking skills, and help students solve more complex problems (Rizqi, 2016; Çelik & Güzel, 2017; Jenab et al, 2018)). Additionally, mathematical communication skills play a

crucial role in developing higher-order thinking skills, such as reasoning, problem solving and decision-making (Noor & Ranti, 2019; Noviyana et al, 2019).

The current issue related to mathematics learning, as highlighted by several studies, is teachers' concern in understanding students' mathematical communication skills. This is evident in instructional practices that do not adequately support the development of these competencies (Çelik & Güzel, 2017; Samo & Kartasasmita, 2017). Although teachers have implemented communication strategies, the relationship they establish between student and teacher communication in mathematics instruction remains insufficient (Sigalingging, 2022; Qalbas, 2018). In practice, these strategies have not been fully effective in fostering meaningful mathematical communication, which is crucial for students' understanding and application of mathematical concepts (Çelik & Güzel, 2017). For teachers to use communication strategies effectively, classroom interaction in mathematics should emphasize three dimensions: (1) student learning, (2) the reasoning process, and (3) knowledge (Kaya & Aydin, 2016; Brendefur et al, 2000).

Students develop their communication capacity during the work process; planning, creating, reflecting, and solving problems together, determining solutions, and expressing the solutions and problems they have resolved (Jefferson & Anderson, 2017; Binkley et al, 2012). Students develop communication capacity in three ways: 1) perceiving and analyzing information outside the classroom; 2) selecting information and media to suit their tasks; and 3) using various forms of communication (Soparat, et al., 2015).

In addition to being crucial in mathematics learning, both oral and written mathematical communication skills are essential components of education (Lomibao et al, 2016). One of the primary priorities in mathematics education is problem-solving, which is a key aspect of mathematical thinking. This highlights the need to integrate problem-solving as a central objective of the mathematics curriculum (NCTM, 2020). Effective mathematical communication plays a vital role in developing students' mathematical thinking skills. Teachers are instrumental in creating an environment that promotes students' mathematical thinking and understanding (Cobb, et al., 1997; Cooke & Buchholz, 2005; Hulukati, 2015).

Differences in students' abilities will affect their capacity to solve mathematical problems. According to the Kamus Besar Bahasa Indonesia (2016), ability refers to strength, proficiency, and capability. In this context, students' abilities are determined based on their performance in assessments and evaluations, which categorize them into high, moderate, or low proficiency levels. These levels are typically established through

standardized tests, classroom observations, or teacher assessments that measure students' understanding of mathematical concepts and their problem-solving skills. These differences are related to students' communication skills in problem-solving.

To improve students' written mathematical communication skills accurately and effectively, it is essential for teachers to teach mathematics using proper symbols, mathematical sentences, and correct mathematical language (Rohid & Rusmawati, 2019; Tong et al, 2021). Secondary school mathematics teachers often do not possess the communication skills in mathematical language expected of a mathematics teacher (Kabel, 2012). This statement emphasizes the importance of cultivating mathematical communication among students as a key factor in enhancing their overall mathematical potential (Efendi et al, 2022). By developing their communication skills, students can better articulate their mathematical thinking, which in turn strengthens their problem-solving abilities and deepens their understanding of mathematical concepts. This connection highlights the crucial role of communication in supporting students' overall growth in mathematics (Herman et al, 2024; Powell, 2021; Tumangger et al, 2024).

Preliminary studies have found that students' written mathematical communication skills in problem-solving tend to be lacking (Chasanah & Usodo, 2020; Tong, 2021). Students' mathematical communication abilities are generally categorized as poo (Tingungki, 2015; Graham, 2014). This is due to weak understanding of concepts, a lack of comprehension regarding the use of mathematical symbols, and students' inability to effectively work through and solve problems (Alfarisyi & Sutiarso, 2020).

Given these issues and supported by the findings of previous research, this study focuses on the activity of students' written mathematical communication skills in solving mathematical problems. By examining students' written mathematical communication in problem-solving, information on these skills will be obtained, which can contribute to the development of mathematics education. Based on the above background, this research will explore "The Profile of Secondary School Students' Written Mathematical Communication Through Problem-Solving Assessment Viewed from Differences in Mathematical Ability."

METHODS

The method used in this study is descriptive research with a qualitative approach. The problem-solving assessment employed includes a problem-solving test and a semi-structured interview guide. The study was conducted at SMP Negeri 1 Sinjai with eighth-grade students during the second semester of the 2023/2024 academic year. The subjects of

the study were three eighth-grade students, each representing low, medium, and high levels of ability. The subjects were selected by administering a preliminary mathematics ability test, followed by choosing three students who met the categories of low, medium, and high mathematical ability. Subsequently, these three students were individually given the problem-solving assessment according to the predetermined time allocation. The following is the story problem material on flat shapes used in this study.

> Sebuah lapangan berbentuk persegi panjang dengan ukuran panjang 100 m dan lebar 65 m. Di dalam lapangan, tepatnya dibagian tepi akan dibuat jalan dengan lebar 5 m mengelilingi lapangan. (a) Gambarkan sketsa jalan yang berada di dalam lapangan serta tuliskan simbol pada setiap titik sudutnya dan tuliskan juga ukuran pada setiap gambar tersebut. (b) Hitunglah luas jalan yang berada dalam lapangan tersebut!

Figure 1. Problem-Solving Test

Indicators of students' written mathematical communication skills are developed from components of mathematical communication (NCTM, 2020). Below is Table 1, which shows the indicators of written mathematical communication associated with Polya's problem-solving stages.

Table 1. Indicators of Written Mathematical Communication Skills in Mathematical Problem Solving

NCTM (2020)	Indicators of Written Mathematical Communication Skills	Problem-Solving Steps
The ability to express mathematical ideas or concepts, both in writing and orally	Expressing mathematical ideas by writing down the information given and the questions asked in a problem, as well as drawing sketches or diagrams.	Understanding Problem
The ability to understand, interpret, and evaluate mathematical ideas or concepts, both in writing and orally	Understanding mathematical ideas to formulate a plan for solving the problem.	Devising a Plan
	Interpreting mathematical ideas while implementing the problem-solving plan.	Carrying out The Plan
	Evaluating the answer by checking the correctness of the solution or conclusion.	Looking Back

Table 2. Scoring Guidelines for Mathematical Communication Skills

Score	Criteria
4	Response is complete, with accurate and clear information, presenting formulas and a comprehensive and logical calculation process.
3	Response is correct or clear, presenting formulas and a complete calculation process.
2	Response is unclear or incorrect, with presented formulas or calculation processes being incomplete.
1	Response is unclear and incorrect, with presented formulas and calculation processes being incomplete.
0	Response is inefficient, with no answers provided, or the answer sheet is blank.

Table 3. Categories of Achievements in Students' Written Mathematical Communication Skills

Achievements in Written Mathematical Communication Skills	Category
0 – 59	Rendah
60 – 79	Sedang
80 – 100	Tinggi

The data obtained from the study will be subject to data reduction. Data reduction involves analyzing the results of the written problem-solving test and the interview results. Data presentation will be carried out by describing the results of the written test and interviews.

RESULT AND DISCUSSION

The problem-solving test was administered to 25 students with a duration of 45 minutes. The test was completed by research subjects selected based on a mathematics ability test and recommendations from the teacher. Three students were chosen: one with high ability, one with medium ability, and one with low ability. After completing the problem-solving test, the students' work was scored. The scores obtained were categorized into high, medium, and low mathematical ability levels. There are 3 students classified in the High proficiency level, 13 students in the Medium proficiency level, and 9 students in the Low proficiency level.

Based on the mathematics ability test and teacher recommendations, three research subjects were selected: one student with high ability, one with medium ability, and one with low ability. After selection, each subject completed the problem-solving test within 45 minutes. Following the test, the researcher conducted interviews with the subjects individually. The researcher analyzed the results of the answers and interviews of the three subjects and found that each subject exhibited different tendencies for each indicator. There are three levels of mathematical ability: Low, Medium, and High. For the Low category, the subject with the initials FDM (S3) has a score of 45. In the Medium category, the subject with the initials RIM (S2) has a score of 70. Lastly, in the High category, the subject with the initials FK (S1) has a score of 85. This shows the different scores corresponding to the selected subjects' mathematical abilities.

Table 4 presents the data analysis of the three subjects in solving mathematical problems based on the indicators from Table 1.

Table 4. Results of Students' Answer Analysis

Subject	Indicators of Written Mathematical Communication Skills			
	Ind 1	Ind 2	Ind 3	Ind 4
S1	√	√	√	√
S2	-	√	-	-
S3	-	-	-	-

From Table 4, the researcher found that each subject had different approaches to solving mathematical problems, particularly with regard to the indicators of understanding mathematical ideas to formulate a plan for solving problems and interpreting mathematical ideas while implementing the problem-solving plan.

Subject with High Mathematical Ability (S1)

Below are the answers from the student with high mathematical ability, who was selected as the subject for solving mathematical problems.

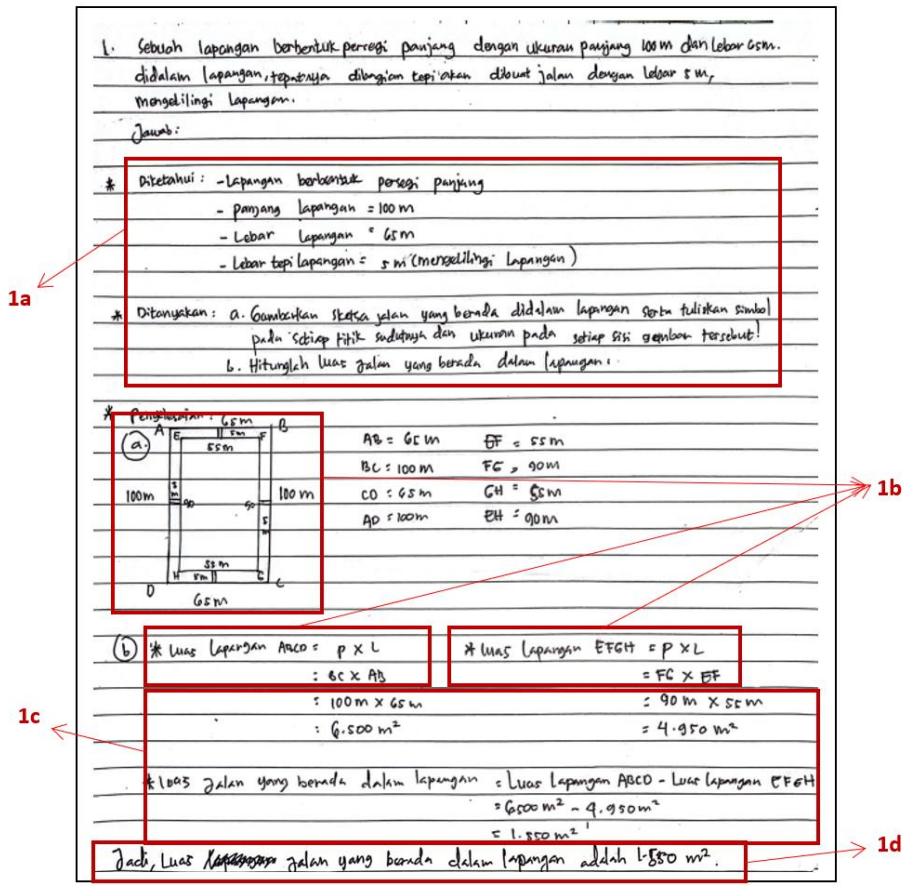

Figure 2. Results of Subject S1's Answers

From Figure 2, the answers of Subject S1, who represents the high mathematical ability group, are evaluated as follows. The subject is considered to meet Indicator 1 if they can write down all the information given and the questions asked. In 1a, S1 successfully writes down the given information and the questions, draws a sketch, and uses mathematical

symbols accurately. For Indicator 2, the subject meets this criterion if they can understand mathematical ideas to formulate a plan. In 1b, S1 writes down the rules or steps to solve the problem based on the information recorded earlier. Regarding Indicator 3, the subject is said to meet this if they can interpret mathematical ideas while implementing the problem-solving plan. In 1c, S1 performs the calculations correctly according to the formulas written in the previous steps or rules. Finally, Indicator 4 requires the subject to verify the correctness of their answer or conclusion. In 1d, S1 writes down the conclusion in response to the problem and, during the interview, confirms that they have checked their answers against the situation provided in the test.

The seventh-grade students who demonstrate high mathematical ability are able to meet all four indicators of written mathematical communication (Sugiarto & Budiarto, 2014). Students with high written mathematical communication skills excel in solving mathematical problems (Isroil, et al., 2017).

Subject with Moderate Mathematical Ability (S2)

Below are the answers from the student with moderate mathematical ability, who was selected as the subject for solving mathematical problems related to planar geometry.

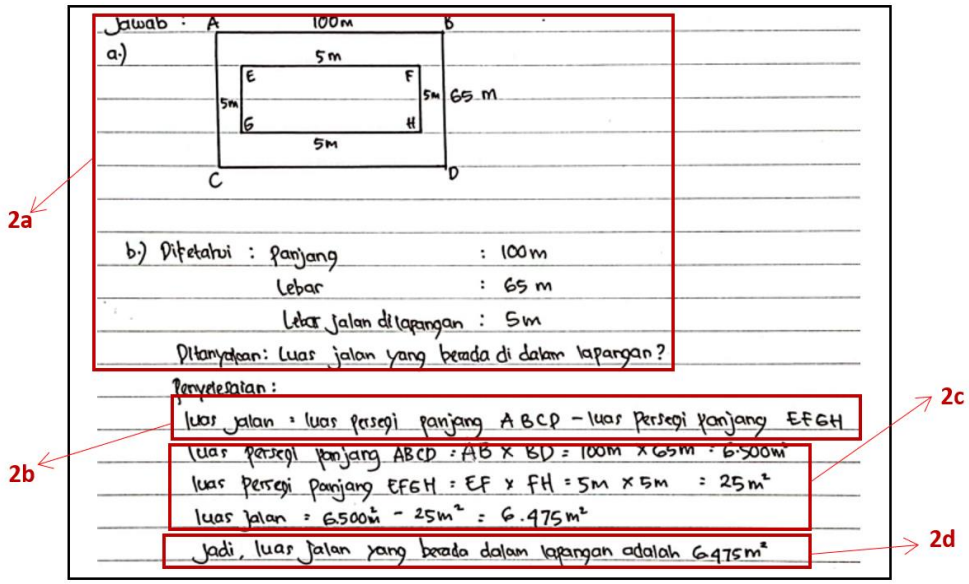

Figure 3. Results of Subject S2's Answers

From Figure 3, the answers of Subject S2, representing the moderate mathematical ability group, are evaluated as follows. The subject is considered to meet Indicator 1 if they can write down the information given and the questions asked. In 2a, S2 writes down the given information and the questions, but with some inaccuracies; the sketch is also somewhat incorrect, though mathematical symbols are used appropriately. For Indicator 2,

the subject meets this criterion if they can understand mathematical ideas to formulate a plan. In 2b, S2 manages to write down the rules or steps for solving the problem. Regarding Indicator 3, the subject is said to meet this if they can interpret mathematical ideas while implementing the problem-solving plan. In 2c, S2 makes errors in the calculations due to imprecise information. Finally, for Indicator 4, the subject should verify the correctness of their answer or conclusion. In 2d, S2 only draws a conclusion without checking whether it aligns with the test situation and makes mistakes in formulating the rules.

In this study, students with moderate mathematical ability were found to be unable to accurately write down the given information and the questions asked. They struggled with the calculation process and were less precise in verifying the correctness of their final answers or conclusions against the problem information. This finding aligns with previous research, which also highlighted that students with moderate mathematical ability often experience difficulties in accurately interpreting problem statements and in systematically applying appropriate problem-solving strategies (Widyatiningtyas et al., 2015; Hulukati, 2015). These studies similarly observed that such students tend to make errors in both the calculation process and in reviewing their final conclusions, reinforcing the need for targeted interventions to improve their problem-solving skills.

Subject with Low Mathematical Ability (S3)

Below are the answers from the student with low mathematical ability, who was selected as the subject for solving mathematical problems.

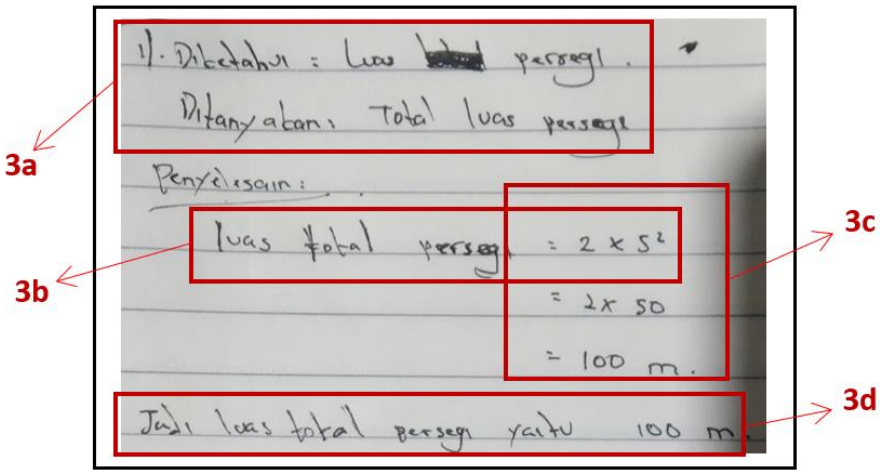

Figure 4. Results of Subject S3's Answers

Based on Figure 4, the results of the answers of subject S3 who represents the low mathematical ability group. The subject is said to have fulfilled indicator 1 if he is able to

provide information on what is known and asked. In 3a, it is known that S3 did not write down the information that was asked and did not make a sketch of the question asked and did not use mathematical symbols correctly. The subject is said to have fulfilled indicator 2 if he is able to understand mathematical ideas to make a plan. In 2b, S3 wrote down the rules or steps for solving incorrectly and incorrectly. The subject is said to have fulfilled indicator 3 if he is able to interpret mathematical ideas in implementing the problem-solving plan. In 3c, S3 made a mistake in the calculation process, namely 52 = 50. The subject is said to have fulfilled indicator 4 if he is able to re-check the correctness of the answer/conclusion. In 3d, S3 only drew a conclusion without re-checking whether the conclusion he wrote was correct or not.

In this study, students with low mathematical ability were unclear in writing down what information was known and asked, made errors in the calculation process, used mathematical symbols incorrectly, and were less accurate in verifying the correctness of the final results or conclusions they wrote. Students with low mathematical ability in their written mathematical communication were incorrect and imprecise in their calculation processes and conclusion drawing. According to this study, students with low ability were inaccurate in understanding information and problems, made mistakes in planning, were inaccurate in the calculation process, and did not draw conclusions that should align with the information contained in the problem (Sugiarto & Budiarto, 2014).

Profile of Written Mathematical Communication Skills of Junior High School Students with High Mathematical Ability in Problem Solving

Students with high mathematical ability, at the stage of understanding the problem, write down what is understood and questioned on the given problem-solving test completely, accurately, and clearly. In the planning stage, students with high mathematical ability are able to draw a sketch with correct annotations aligned with what has been understood and questioned. At the stage of implementing the problem-solving plan, students with high mathematical ability present formulas and perform calculations that are complete and logical. In the checking stage, students with high mathematical ability correctly review the results according to the calculations and write out the method for solving the problem in a clear, complete, and logical manner.

Previous research supports these findings, showing that students with high mathematical ability tend to excel in all stages of problem solving, including the ability to clearly communicate their thought process in writing. According to Widyatiningtyas et al.

(2015) and Hulukati (2015), students with high ability can systematically organize and present the information needed for problem solving, accurately plan solutions, and effectively evaluate their work. These studies also found that such students are more likely to engage in reflective thinking when reviewing their solutions, ensuring that their conclusions align with the problem's requirements. This suggests that students with high mathematical ability demonstrate strong written mathematical communication, as they are able to articulate each step of the problem-solving process clearly and logically.

Profile of Written Mathematical Communication Skills of Junior High School Students with Medium Mathematical Ability in Problem Solving

Students with moderate mathematical ability, at the stage of understanding the problem, write down what they have understood and what is being asked in the problem-solving test, but their responses tend to be incomplete and unclear. At the planning stage, these students can draw a sketch with annotations, although some inaccuracies are present in their representations. In the execution stage, students with moderate mathematical ability attempt to present formulas and perform calculations, but their work is often incomplete and lacks logical coherence due to insufficient or incorrect information about what is known and what is being asked. At the checking stage, these students do not adequately verify or review their results in accordance with the calculations, leading to incomplete or incorrect conclusions.

Previous research has identified similar challenges faced by students with moderate mathematical ability. According to Widyatiningtyas et al. (2015), students in this category often struggle with clarity and completeness in their written responses, particularly in the stages of planning and execution. They are less likely to engage in reflective processes when reviewing their solutions, which further contributes to inaccuracies in their final answers. These findings align with the results of Hulukati (2015), who also observed that students with moderate ability tend to misapply mathematical concepts, resulting in illogical or incomplete calculations and an overall lack of precision in verifying their work.

Profile of Mathematical Communication Skills in Written Form of Junior High School Students with Low Mathematical Ability in Problem Solving

Students with low mathematical ability, at the stage of understanding the problem, are inefficient in articulating what they have understood and what is being asked in the given problem-solving test. Their responses tend to be vague and lack detail. At the

planning stage, students with low mathematical ability do not present relevant rules or formulas to guide their problem-solving process. During the execution stage, these students often misinterpret the problem, leading to errors in their calculations due to a lack of clear understanding of the information provided and what is required. At the final checking stage, students with low mathematical ability fail to correctly verify or review their results, leading to incomplete or incorrect conclusions.

Previous research supports these findings, highlighting the common difficulties faced by students with low mathematical ability in problem solving. According to studies by Widyatiningtyas et al. (2015) and Hulukati (2015), these students frequently struggle with clearly expressing mathematical ideas in writing and tend to miss crucial steps in the problem-solving process. They also demonstrate a lower capacity for reflection and self-correction, which affects their ability to review and verify their answers accurately. This lack of clarity and precision is a common challenge among students with lower mathematical proficiency.

CONCLUSION

Based on the research findings and discussion, the profile of students' mathematical communication skills in writing can be summarized as follows: High-ability students meet all four indicators of mathematical communication skills in writing, which include documenting what is known and asked from the given problem and drawing a sketch; understanding mathematical ideas in planning and creating rules or presenting formulas; interpreting information when implementing the problem-solving plan; and checking/verifying the correctness of answers and conclusions. Students with moderate mathematical ability meet one indicator, which is understanding mathematical ideas to plan and create rules or present formulas. Students with low mathematical ability do not meet any of the indicators of mathematical communication skills in writing.

The findings of this study are expected to be used as considerations in developing assessments, and it is hoped that teachers will be able to recognize students' mathematical communication skills according to their varying abilities, thus assisting students in developing their skills.

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