

# GENDER DIFFERENCES IN WRITTEN MATHEMATICAL COMMUNICATION: AN ANALYSIS OF STUDENTS' PROBLEM-SOLVING PROCESSES

Pieter Zakarias Tupamahu<sup>1</sup>, Christina M. Laamena<sup>2</sup>, Nelma Dortje Lethulur<sup>3</sup>

<sup>1</sup>Universitas Pattimura, Jl. Ir. M. Putuhena, Ambon, Indonesia.

[pietertpmhu1@gmail.com](mailto:pietertpmhu1@gmail.com)

<sup>2</sup>Universitas Pattimura, Jl. Ir. M. Putuhena, Ambon, Indonesia.

[christinmath18@gmail.com](mailto:christinmath18@gmail.com)

<sup>3</sup>Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung, Indonesia.

[dortjelethulur@gmail.com](mailto:dortjelethulur@gmail.com)

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## ABSTRACT

In mathematics education, written mathematical communication (WMC) is crucial for students to articulate problem-solving processes, yet gender differences and underlying weaknesses in high school contexts remain underexplored, particularly in linear programming tasks. This study aims to analyze the WMC of eleventh-grade high school students in solving linear programming problems from a gender perspective. A sequential explanatory mixed-methods approach was employed with 44 students from Ambon City high schools. Quantitative data from WMC assessments were analyzed using descriptive statistics and multiple linear regression to evaluate overall performance, indicator dominance (accuracy vs. completeness), and gender effects. Six participants were then purposively selected for semi-structured interviews based on ability levels (high, medium, low) and gender, providing qualitative insights into problem-solving phases. Results showed low overall WMC (male dominance: 27.4%; female: 29.6%), with accuracy ( $M = 53.54\text{--}54.5\%$ ) outperforming completeness ( $M = 32.32\text{--}32.83\%$ ). Regression analysis indicated no significant gender effect. Interviews revealed systematic weaknesses in the entry phase (contextual data interpretation), attack phase (symbolic-graphic representation), and review phase (reflective evaluation). These findings highlight that WMC depends not only on computational skills but also on metacognitive abilities for coherent argumentation. Teachers should implement reflection-based learning to foster contextual writing, comprehensive visual labeling, and evaluative conclusions.

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### Corresponding Author:

Pieter Zakarias Tupamahu,  
Department of Mathematics Education,  
Universitas Pattimura,  
Jl. Ir. M. Putuhena, Ambon, Indonesia  
Email: [pietertpmhu1@gmail.com](mailto:pietertpmhu1@gmail.com)

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## INTRODUCTION

Mathematics education plays a crucial role in developing students' logical, analytical, critical, and systematic thinking abilities. National Council of Teacher of Mathematics/(NCTM, 2023) outlines five key objectives for mathematics learning: (1) learning to communicate mathematically (mathematical communication); (2) learning to reason mathematically (mathematical reasoning); (3) learning to solve problems mathematically (mathematical problem solving); (4) learning to connect ideas mathematically (mathematical connections); and (5) learning to represent ideas mathematically (mathematical representation). Problem solving serves as the core of mathematics education, requiring students to comprehend situations, devise strategies, and interpret results through coherent logical reasoning (Husna & Burais, 2019; Rodley & Bailey, 2021). Through problem solving, mathematics retains its meaningfulness, as a concept or principle becomes significant when it enables students to achieve optimal mastery of problem-solving abilities (Brand et al., 2023; Rizza, 2021).

Mason et al., (2010) propose that problem-solving consists of three interconnected phases, each comprising three distinct aspects: [1] entry (know, want, introduce), representing the phase of information assimilation into cognitive processing; [2] attack (try, maybe, why), involving critical questioning of validity and exploration of potential solution pathways; [3] review (check, reflect, extend which entails evaluation and verification of obtained results. These phases are interdependent and iterative rather than strictly linear, allowing cyclical navigation as needed. Furthermore, according to (Gilligan-Lee et al., 2022; Kurnila et al., 2023), mathematical problem solving manifests through solving narrative word problems, tackling non-routine tasks, and applying mathematics to everyday contexts. Effective resolution demands deeper cognitive engagement to yield accurate and optimal outcomes.

In practice, many students still encounter difficulties in systematically constructing problem-solving steps, particularly when faced with tasks that extend beyond mere formula application (Rahayuningsih et al., 2020; Ukobizaba et al., 2021). This challenge pertains not only to conceptual understanding but also to effectively communicating mathematical thought processes. Written mathematical communication plays a pivotal role in constructing and expressing mathematical ideas clearly and systematically. Proficiency in mathematical communication is essential in mathematics education, as students with strong communication skills can more readily interpret and resolve problems (Reuter, 2023; Rohid et al., 2019; Sumaji et al., 2020). Mathematical problem solving necessitates mathematical communication abilities, given their interconnected nature as integral steps toward resolving mathematical problems (La'ia & Harefa, 2021; Rizza, 2021).

Effective mathematical communication skills are essential for conveying understanding, ideas, and arguments in mathematical problem solving, whether in written or oral form, ensuring that such expressions are comprehensible to others. Asmana (2018) emphasizes the critical importance of written mathematical communication (WMC) in mathematics learning. WMC entails expressing mathematical ideas through symbols, diagrams, vocabulary, and notation in written form between two or more individuals without alteration, thereby enabling accurate message comprehension. In addition (Asmana et al., 2018) assert that accuracy is paramount in mathematical communication due to the subject's inherently rigorous characteristics. A written statement or expression is deemed

complete when no essential elements are omitted. Thus, completeness in written mathematical communication can be defined as providing sufficient information to resolve the problem effectively.

In learning mathematics or solving problems, psychological readiness constitutes a key factor for students, with learning psychology being influenced by students' own psychological characteristics (Hutajulu et al., 2019; Rahman et al., 2022). Gender differences can lead to variations in students' learning psychology. Consequently, male and female students exhibit distinct differences in their approaches to mathematics learning (Mashuri & Yawan, 2023; Pina et al., 2021). Gender differences contribute to explaining individuals' profiles in problem solving and communicating results; however, these differences remain inconsistent (Utami et al., 2023). Thus, inconsistencies in research findings involving gender comparisons across different age groups and cultural contexts cannot be attributed solely to gender.

Existing research demonstrates differences in learning styles and cognitive strategies between male and female students (Kamid et al., 2020; Lanya et al., 2020; Mainali, 2021; Reinhold et al., 2020), males tend to exhibit stronger visual-spatial orientation, while females demonstrate greater verbal and detail-oriented tendencies. Consequently, a critical question arises regarding how these differences influence written mathematical communication when students confront complex problem-solving tasks. Numerous core mathematics topics actively engage both written mathematical communication and problem-solving abilities. Linear programming represents one such topic studied by eleventh-grade high school students. Learning linear programming aims to identify solutions to problems by first constructing mathematical models and solving them through various mathematical expressions, including graphs, diagrams, illustrations, or tables.

In the context of linear programming, problem-solving abilities require students to translate contextual situations into mathematical models comprising systems of two-variable linear inequalities, graphically determine feasible regions, and identify optimal values of objective functions. (Ningtyas & Ekawati, 2021; Sukoriyanto et al., 2021) note that common difficulties include students' struggles to articulate inter-variable relationships, accurately depict solution regions, and systematically justify computational steps. Such challenges reveal deficiencies in written mathematical communication, as students often replicate procedures without documenting the underlying reasoning. Linear programming instruction should emphasize verbal and written exploration through reflective thinking processes, training students to explicate each transformation from contextual problems to mathematical forms.

Accordingly, examining written mathematical communication in problem-solving contexts from a gender perspective constitutes a study poised to make theoretical contributions toward understanding the interplay among problem-solving abilities, written mathematical communication, and gender differences in linear programming topics.

## **METHOD**

This study employed a mixed methods research design with a sequential explanatory strategy, wherein quantitative data were collected and analyzed first, followed by qualitative data to provide detailed explanations of the quantitative findings (Creswell & Clark, 2018).

The research involved 44 eleventh-grade high school students from a school in Ambon City as the data sources. Interview subjects comprised six students selected based on ability levels and gender: S1 (male) and S2 (female) representing very high and high categories; S3 (male) and S4 (female) representing the medium category; and S5 (male) and S6 (female) representing low and very low categories. Data were gathered through written tests and interviews, with test instruments and interview protocols validated by experts. Necessary revisions were made based on expert feedback and recommendations until the instruments were deemed valid.

Quantitative data analysis in this study employed descriptive statistics. At this stage, test results for written mathematical communication abilities were obtained by scoring students' responses for each test item. The assessment guidelines used were the Criterion-Referenced Assessment/*Penilaian Acuan Patokan* (PAP) rubric. According to Ratumanan dan Laurens (2015) categories are presented in Table 1 below.

**Table 1.** Criterion-Referenced Assesment (*Penilaian Acuan Patokan*/PAP)

| Category  | Value Interval   |
|-----------|------------------|
| Very High | $x \geq 90$      |
| High      | $75 \leq x < 90$ |
| Medium    | $60 \leq x < 75$ |
| Low       | $40 \leq x < 60$ |
| Very Low  | $x < 40$         |

The qualitative data analysis techniques followed the steps outlined by Miles and Huberman (Sugiyono, 2019): [1] Data Reduction [2] Data Display and [3] Verification. The triangulation method employed in this study was methodological triangulation. Methodological triangulation involves using various data collection techniques to obtain information from the same source (Sugiyono, 2019).

## RESULTS AND DISCUSSION

### Results

Based on the test data obtained from 44 students, the results were then described in various forms of presentation. The data on students' written mathematical communication skills derived from the test results are presented in a table. The classification of students' written mathematical communication skills based on gender can be seen in Table 2 below.

**Table 2.** Written Mathematical Communication Skills Test Results Based on Gender

| Interval         | Category  | Gender | Frequency | Percentage (%) |
|------------------|-----------|--------|-----------|----------------|
| $x \geq 90$      | Very High | Male   | 0         | 0%             |
|                  |           | Female | 0         | 0%             |
| $75 \leq x < 90$ | High      | Male   | 2         | 4.5%           |
|                  |           | Female | 2         | 4,5%           |
| $60 \leq x < 75$ | Medium    | Male   | 2         | 4.5%           |
|                  |           | Female | 3         | 6.8%           |
| $40 \leq x < 60$ | Low       | Male   | 6         | 13.6%          |
|                  |           | Female | 4         | 9.1%           |
| $x < 40$         | Very Low  | Male   | 12        | 27,4%          |
|                  |           | Female | 13        | 29.6%          |
| Total            |           |        | 44        | 100%           |

From Table 2, it can be observed that in the high category, there are 0 students (0%) for both male and female genders. In the medium category, there are 2 male students (4.5%) and 4 female students (9.1%). In the low category, there are 9 male students (20.5%) and 12 female students (27.3%). Meanwhile, in the very low category, there are 11 male students (25%) and 17 female students (38.6%). Thus, it can be concluded that the largest percentage of written mathematical communication skills test results for students, both male and female, falls in the very low category.

In addition to grouping by frequency for overall written communication skills, a table of average scores can also be constructed based on two indicators of written mathematical communication: Accuracy and Completeness. The following table presents the average scores for these two indicators of written mathematical communication

**Table 3.** Average Scores of Written Mathematical Communication Indicators by Gender

| No.   | Indicator    | Maximum Score | Gender | Score                        |                    |
|-------|--------------|---------------|--------|------------------------------|--------------------|
|       |              |               |        | $\bar{X}$<br>(Average Score) | %<br>(Percentage ) |
| 1.    | Accuracy     | 9             | Male   | 4.82                         | 53.54%             |
|       |              |               | Female | 4.91                         | 54.5%              |
| 2.    | Completeness | 9             | Male   | 2.91                         | 32.32%             |
|       |              |               | Female | 2.95                         | 32.83%             |
| Total |              | 18            |        |                              |                    |

Based on Table 3, the written communication indicators, namely accuracy and completeness, each have a maximum score of 9, as they consist of 3 items. Quantitative data analysis reveals that female students achieved the highest average score of 4.91 (54.5%) on the accuracy indicator and the lowest average score of 2.95 (32.8%) on the completeness indicator. In contrast, male students recorded their highest average score of 4.82 (53.5%) on the accuracy indicator and their lowest average score of 2.95 (32.8%) on the completeness indicator.

**Table 4.** Coefficients of the Relationship Between Gender and Mathematical Communication Ability

| Coefficients <sup>a</sup> |                             |            |                           |       |      |
|---------------------------|-----------------------------|------------|---------------------------|-------|------|
| Model                     | Unstandardized Coefficients |            | Standardized Coefficients | t     | Sig. |
|                           | B                           | Std. Error | Beta                      |       |      |
| (Constant)                | 42.273                      | 9.335      |                           | 4.528 | .000 |
| <i>GENDER</i>             | .727                        | 5.904      | .019                      | .123  | .903 |

a. Dependent Variable: **Written Mathematical Communication**

The results from Table 4 indicate that the employed regression model reveals no significant influence of gender on students' written mathematical communication skills. The constant value of 42.273 with a significance level of 0.000 suggests that, irrespective of gender differences,

the average written mathematical communication ability is approximately 42.27, a finding that is statistically significant. The regression coefficient for the gender variable stands at 0.727, accompanied by a t-value of 0.123 and a significance level of 0.903 far exceeding the 0.05 threshold indicating that gender differences do not contribute meaningfully to the variation in written mathematical communication scores. In other words, variations in written mathematical communication proficiency cannot be attributed to gender factors; empirically, this implies that male and female students possess relatively equal opportunities to attain comparable levels of such skills within the context of linear programming problem-solving.

During the implementation phase, subjects representing the categories of very high, high, medium, low, and very low ability were administered a written test on mathematical communication skills. The questions provided for analyzing the thought processes underlying written mathematical communication skills were as follows:

- 1) Determine the feasible region for the following system of linear inequalities:
  - i.  $2x + y \leq 9$ ,
  - ii.  $x + 3y \leq 12$ ,
  - iii.  $x \geq 0$
  - iv.  $y \geq 0$
- 2) Citraland Company, operating in the property business, plans to construct two types of houses (Diamond and Ruby) on a 18,000 m<sup>2</sup> plot of land. Each Diamond-type house requires 200 m<sup>2</sup>, and each Ruby-type house requires 120 m<sup>2</sup>. The total number of Diamond and Ruby houses to be built is at most 100 units. The profit from each Diamond-type house is Rp30,000,000 per unit, and from each Ruby-type house is Rp25,000,000 per unit. Formulate the mathematical model and determine the maximum profit that can be obtained from selling these houses!
- 3) The weekly minimum requirements for protein, carbohydrates, and fat for a boxer athlete are 16 units, 24 units, and 18 units, respectively. Food type A per kg contains 2 units of protein, 6 units of carbohydrates, and 1 unit of fat. Meanwhile, food type B per kg contains 1 unit of protein, 1 unit of carbohydrates, and 3 units of fat. If the price of food type A is Rp50,000/kg and food type B is Rp40,000/kg, determine the minimum amount in rupiah that must be spent over 6 months to meet the athlete's protein, carbohydrate, and fat requirements.

Figure 1 below shows one example of problem-solving for question number 2 based on gender from male and female subjects in solving those three problems. Furthermore, Table 1 provides a description of the accuracy indicators for written mathematical communication skills in linear programming problem-solving, categorized by the gender of the subjects.

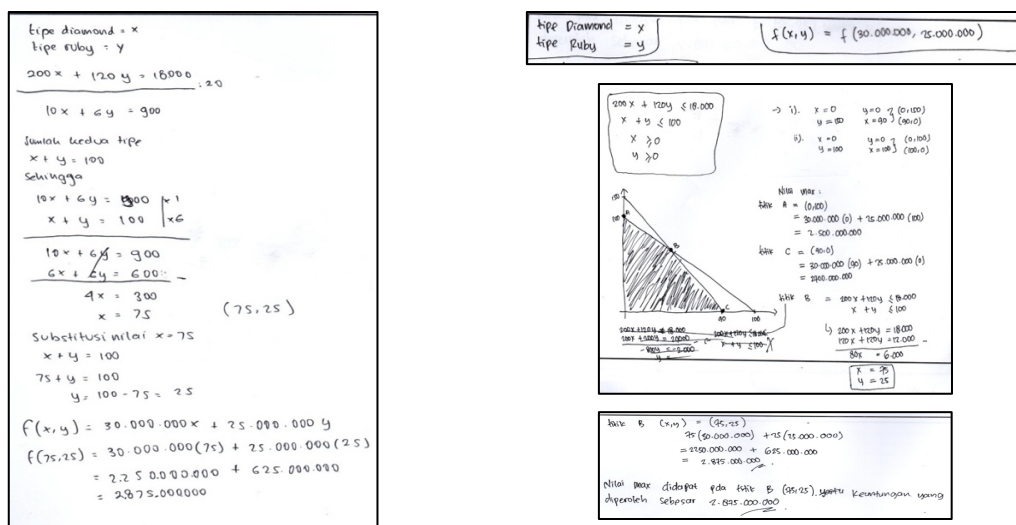


**Figure 1.** Example of work results from subjects: (left) male, (right) female

**Table 5.** Description of Accuracy Indicators for Written Mathematical Communication Skills in Linear Programming Problem-Solving by Gender

| <b>Problem Solving</b> | <b>Male Subject</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Female Subject</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Entry Phase            | For questions 1, 2, and 3, the subjects did not present the known information or what was being asked in relation to communication accuracy, as they assumed this was already stated in the problem itself.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>• For question 1, the subject successfully determined the solution by converting inequalities into equations, identifying the x- and y-axis intercepts, and graphing the solution accordingly.</li> <li>• For questions 2 and 3, the subject omitted writing the known information and what was being asked, having already comprehended the problem's intent.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                     |
| Attack Phase           | <ul style="list-style-type: none"> <li>• For question 1, the subject documented the computational operation steps in accordance with the problem's intent, such as accurately calculating the intercepts on the x- and y-axes.</li> <li>• For question 2, the subject outlined the computational operation steps aligned with the problem's purpose, including formulating the mathematical model from the table, determining intercepts on the x- and y-axes from the inequalities, graphing the feasible region, and identifying the maximum profit.</li> <li>• For question 3, the subject recorded the computational operation steps consistent with the problem's objective, such as constructing the mathematical model from the table, calculating intercepts on the x- and y-axes from the three inequalities, and proceeding to determine the minimum value.</li> </ul> | <ul style="list-style-type: none"> <li>• For question 1, the subject documented the computational operation steps, such as accurately calculating the intercepts on the x- and y-axes from the inequalities and testing the point (0,0).</li> <li>• For question 2, the subject outlined the computational operation steps in accordance with the problem's intent, including determining intercepts on the x- and y-axes from the inequalities, graphing the feasible region, and identifying the maximum profit.</li> <li>• For question 3, the subject recorded the computational operation steps, such as formulating the mathematical model, calculating intercepts on the x- and y-axes from the three inequalities, and proceeding to determine the minimum value.</li> </ul> |

| Problem Solving | Male Subject                                                                                                                                                                                                                                                                                                                                                                                                         | Female Subject                                                                                                                                                                                                                                                                                                                       |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Review Phase    | <ul style="list-style-type: none"> <li>• For question 1, the subject reviewed the corner points obtained from the calculation results.</li> <li>• For question 2, the subject did not recheck the work results but felt there were deficiencies in the outcomes due to calculation errors.</li> <li>• For question 3, the subject did not verify the work results in accordance with the steps performed.</li> </ul> | <ul style="list-style-type: none"> <li>• For questions 1 and 2, the subject did not verify the work results in accordance with the steps performed.</li> <li>• For question 3, the subject rechecked the work results by, for instance, recalculating the amount of food in kg obtained per month and testing each point.</li> </ul> |

The first indicator of written mathematical communication skills is accuracy. (1) In the Entry Phase, both male and female subjects demonstrated comprehension of the problem's intent and thus did not rewrite the known information or questions on the answer sheet. However, the female subject successfully determined the solution for question 1 by converting inequalities into equations, identifying the x- and y-axis intercepts, and graphing the solution. (2) In the Attack Phase, both male and female subjects effectively addressed the given problems. They documented computational operation steps aligned with the problem's objectives, including mathematical model formulation, determination of x- and y-axis intercepts from inequalities, and identification of optimal values. (3) In the Review Phase, the male subject only verified the work for question 1, specifically rechecking corner point calculations, but did not review questions 2 and 3 despite sensing calculation errors.

In contrast, the female subject reviewed only question 3, recalculating food quantities in kg per month and testing each point, while omitting review for questions 1 and 2. The following describes the completeness indicator of written mathematical communication skills in linear programming problem-solving, categorized by subject gender.

**Table 6.** Description of Completeness Indicators for Written Mathematical Communication Skills in Problem-Solving by Gender

| Problem Solving | Male Subject                                                                                                                                                                                                                                                                                                                                                                                                 | Female Subject                                                                                                                                                                                                                                                                                                                                                       |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Entry Phase     | <ul style="list-style-type: none"> <li>• For questions 1 and 3, the subject did not write down the known information and what was being asked, assuming it was already stated in the problem and constrained by time limits, yet fully comprehended the problem's intent.</li> <li>• For question 2, the subject documented all known information from the table but omitted writing the specific</li> </ul> | <ul style="list-style-type: none"> <li>• For question 1, the subject documented the known information from each table description.</li> <li>• For question 2, the subject recorded the known elements, such as house types and the objective function derived from the problem. However, the subject did not specify what was being asked in the problem.</li> </ul> |

| Problem Solving | Male Subject                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Female Subject                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                 | information or questions posed by the problem.                                                                                                                                                                                                                                                                                                                                                                                                                   | •For question 3, the subject omitted the known information and questions, as they were already stated in the problem.                                                                                                                                                                                                                                                                       |
| Attack Phase    | <ul style="list-style-type: none"> <li>• For question 1, the subject provided labels on the constructed graph, including intercepts on the x- and y-axes as well as the feasible region.</li> <li>• For question 2, the subject included labels for each column and row in the table and on the graph.</li> <li>• For question 3, the subject provided labels for each column and row in the table, along with x- and y-axis intercepts on the graph.</li> </ul> | <ul style="list-style-type: none"> <li>•For question 1, the subject provided labels on the constructed graph, such as intercepts on the x- and y-axes and notation for the feasible region.</li> <li>•For question 2, the subject included labels on the constructed graph.</li> <li>•For question 3, the subject provided labels for the x- and y-axis intercepts on the graph.</li> </ul> |
| Review Phase    | <ul style="list-style-type: none"> <li>• For question 1, the subject provided a conclusion and recognized the importance of writing a conclusion, while acknowledging that the conclusion drawn was incomplete.</li> <li>• For question 2, the subject presented information regarding the importance of writing a conclusion from problem-solving work.</li> <li>• For question 3, the subject formulated a conclusion from the given problem</li> </ul>        | <ul style="list-style-type: none"> <li>•For question 1, the subject rechecked the solution by providing notation for the feasible region previously omitted from the graph and by formulating a conclusion.</li> <li>•For question 2, the subject formulated a conclusion.</li> <li>•For question 3, the subject wrote a conclusion addressing the given problem.</li> </ul>                |

The second indicator of written mathematical communication skills is completeness. (1) In the Entry Phase, the male subject documented only the known variables from the table but omitted those being asked. Additionally, for questions 1 and 3, no known or queried variables were recorded, as the subject assumed they were already stated in the problem and was constrained by time. The female subject listed known variables from each table description for question 1 and, for question 2, specified known elements such as house types and the objective function, yet omitted the variables being asked across these questions. For question 3, the female subject similarly excluded known and queried information, deeming it already presented in the problem. (2) In the Attack Phase, both male and female subjects adequately completed the problem-solving process. They provided comprehensive labeling for tables and graphs, including intercepts, x- and y-axes, and feasible region notation. (3) In the Review Phase, both subjects supplemented their work by formulating conclusions for all three questions. For

question 1, the male subject recognized the incompleteness of the conclusion drawn, whereas the female subject added the previously omitted feasible region notation to the graph

### ***Discussions***

The research findings indicate that students' written mathematical communication skills (WMC) in linear programming problem-solving remain at a low level, for both male and female students, as evidenced by the dominance of the very low category in score distribution and the low average scores for accuracy and completeness indicators. This condition indirectly suggests that students have yet to effectively utilize WMC as a means to express and construct understanding of linear programming concepts, despite demonstrating procedural competence in certain solution steps. These findings align with studies by Astuti et al., (2019); Suciwati Sartika et al., (2022), which report that students often focus narrowly on final answers without narrating their thought processes, thereby hindering optimal development of argumentation, reasoning, and mathematical justification. Thus, the core issue lies not merely in computational shortcomings but in deficiencies in organizing and presenting mathematical ideas in a coherent, logical, and revisable written form.

Based on the average scores obtained, female subjects statistically outperformed male subjects on both completeness and accuracy indicators. This is supported by research from Kamid et al., (2020); Utami et al., (2023), which indicates that, overall, female subjects demonstrate superior mathematical communication skills compared to male subjects. This advantage stems from female subjects' greater meticulousness, precision, and patience in solving mathematical problems, enabling them to better articulate mathematical ideas through writing, diagrams, and mathematical expressions. The regression analysis results, with a significance value of 0.903, confirm the absence of a significant gender effect on overall ability. These findings align with Herawati et al., (2023); Winggowati et al., (2023), who concluded that gender differences do not constitute a determining factor in students' mathematical communication skills during problem-solving. Instead, other variables such as socioeconomic background, educational environment, time management, and similar factors play more substantial roles.

Qualitative analysis reveals that male and female subjects exhibit differences in written mathematical communication skills during problem-solving, despite these differences lacking statistical significance. (Yesaya et al., 2021) posit that male and female students possess equivalent abilities, manifested through divergent processes. Male students tend to demonstrate greater proficiency in verbally expressing their work on answer sheets.

Qualitative analysis of written mathematical communication skills (WMC) on the accuracy indicator reveals that both male and female students demonstrate relative competence in fundamental linear programming procedures, such as transforming inequalities into equations, identifying intercepts, plotting graphs, and determining optimal values. However, computational errors and incomplete point testing frequently occur, signaling unstable or inconsistent conceptual understanding during problem resolution. Students can articulate solution steps but often fail to fully grasp the underlying rationale for each procedure, particularly during the review phase, which should facilitate model consistency checks and outcome validation. Studies by (Achir et al., 2017; Caerols-Palma & Vogt-Geisse, 2022; Paridjo & Waluya, 2017) similarly identify this pattern in mathematical communication contexts: students excel in initial procedures yet falter in reflection and verification, yielding solutions that appear initially sound but lack comprehensive accountability. Within the problem-solving framework, these accuracy deficits underscore inadequate integration of problem context, mathematical modeling, and result interpretation.

A more pronounced disparity emerges in the completeness indicator compared to accuracy, characterized by students' tendencies to omit known information and problem queries, provide

incomplete labels on tables and graphs, and neglect explicit written conclusions. This pattern underscores students' failure to regard written explanations as integral to solutions, prioritizing instead diagrams and numerical results, which renders mathematical arguments structurally fragmented and challenging for others to comprehend. Research on written mathematical communication by Hulukati et al., (2022); Ningtyas & Ekawati (2021); Wulandari & Astutiningtyas (2020) elucidates that such completeness deficits undermine problem-solving quality, as instructors cannot discern whether correct answers stem from proper procedures or mere coincidence. In essence, completeness issues transcend mere untidiness, directly implicating students' depth of understanding and metacognitive capacity to systematically manage information and present solutions.

## CONCLUSION

Students' written mathematical communication skills (WMC) in Grade XI high school linear programming problem-solving contexts overall remain at a low level, marked by the predominance of the very low category (27.4% male; 29.6% female) and consistent disparities in average scores between accuracy ( $M_{\text{male}} = 53.54\%$ ;  $M_{\text{female}} = 54.5\%$ ) and completeness indicators ( $M_{\text{male}} = 32.32\%$ ;  $M_{\text{female}} = 32.83\%$ ). These results reflect students' structural deficiencies in communicating concepts through visual, symbolic, and verbal modes.

The employed linear regression analysis demonstrates the statistical insignificance of gender's influence on WMC variability ( $\beta=0.019$ ;  $t=0.123$ ;  $\rho=0.903>0.05$ ), corroborated by qualitative descriptions of divergent thinking patterns between genders that exert minimal impact. Subjects across both genders exhibited systematic weaknesses in the entry phase (neglect of documenting known/queried data), attack phase (inconsistencies in symbolic-graphic operations), and review phase (limited argumentative conclusion reflection), thereby impeding coherent mathematical knowledge construction.

Given the predominant weakness in the completeness indicator, teachers are recommended to implement learning strategies that explicitly train documentation of known/queried information, comprehensive labeling of tables and graphs, and conclusion formulation for each linear programming problem. Future research should examine other identified factors—such as socioeconomic background and time management—that contribute to low WMC, employing ability-category-specific subject selection for more granular analysis.

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