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Analyzing Critical Thinking and Mathematical Communication Skills of Junior High School Students Based on Intrapersonal and Interpersonal Intelligence

Laila Marfirah[1], Kana Hidayati[1], Ramadian Radite[1]

[1]Yogyakarta State University, Departement of Mathematics Education
Daerah Istimewa Yogyakarta 55281, Indonesia

Abstract:
This research aims to analyze the effect of intrapersonal and interpersonal intelligence on students' critical thinking abilities and mathematical communication abilities. A survey was conducted on 368 eighth-grade junior high school students in Yogyakarta City, who were selected using a proportionate stratified random sampling technique based on Regional Education Standardization Assessment scores. Intrapersonal and interpersonal intelligence questionnaires, as well as tests for mathematical communication and critical thinking skills, were used as research instruments. To achieve the result, data were analyzed using descriptive and inferential statistics, with a focus on multivariate regression analysis. The findings indicated that students' critical thinking, mathematical communication skills, as well as intrapersonal and interpersonal intelligent, are in the moderate category. Furthermore, intrapersonal and interpersonal intelligence have significant effect on mathematical communication skills; however, they do not have significant effect on critical thinking skills. The results showed that students with high intrapersonal and interpersonal intelligence tend to demonstrate high critical thinking and mathematical communication skills. Therefore, it is critical for teachers to foster students' intrapersonal and interpersonal intelligence through meaningful learning activity that promote student interaction.

Keywords: critical thinking, mathematical communication, intrapersonal and interpersonal intelligence.

1. Introduction

The objectives of learning mathematics, as stated in the decree of the Head of BSKAP and the guidelines of the National Council of Teachers of Mathematics (NCTM), emphasize several key aspects of mathematical education. Students are expected to understand and apply mathematical concepts appropriately, use reasoning to make generalizations and provide evidence, and solve problems through mathematical modeling (Agustina, et. al. 2024). Additionally, students must be able to communicate ideas using symbols and diagrams while connecting mathematical concepts to various scientific fields and real-life situations. Mathematics education also aims to enhance higher-order thinking skills, develop problem-solving abilities, optimize learning outcomes, improve idea articulation, and foster students' character (Mendikbudristek, 2022).

According to NCTM (2000), there are five essential mathematical abilities that students must possess, namely problem-solving, communication, connections, reasoning, and representation. Greenes (1996) highlighted the importance of mathematical communication in helping students develop mathematical concepts and strategies, conduct investigations and discoveries, and engage in discussions with peers to exchange ideas, acquire information, express opinions, evaluate perspectives, and refine arguments to influence others. Likewise, mathematical communication is critical in the mathematization process transforming concrete problems to abstract concept especially in higher-order thinking problems (Sulistyawati & Radite, 2024). Baroody (1993) identified two key reasons for enhancing mathematical communication among students. First, mathematics serves as a language, not only as a tool for thinking and

problem-solving but also for conveying ideas clearly and accurately. Second, learning mathematics is a social activity that involves interaction between students and teachers, as well as among students themselves.

Supporting student communication is crucial for helping students articulate and clarify their thoughts more objectively (Vale, 2012). Through peer communication, students can exchange knowledge and deepen their understanding of mathematical concepts. Puspita (2016) found that junior high school students struggle to visualize mathematical ideas, which makes it difficult for them to overcome learning obstacles and often leads to mistakes in mathematical exploration. To address this issues, teachers play a vital role in assessing students' mathematical communication skills to monitor conceptual development (Zulkarnain et al., 2021).

One of the primary goals of education is to develop students' critical thinking skills, as these abilities enable them to communicate effectively and solve the problems in complex, and challenging the situations (Basri et al., 2019). Critical thinking is defined as reasonable and reflective thinking that focused on making informed decisions about what to believe or do (Ennis, 2018). Encouraging critical thinking allows students to engage more deeply in learning and apply problem-solving skills beyond the classroom into real-life situations (Jacob, 2012). Facione (2011) identified six components of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation.

Both critical thinking and mathematical communication skills are important, and they should be integrated into mathematics instruction. Communication skills are crucial for students as they contribute to creativity development, while critical thinking skills significantly enhance learning effectiveness, particularly in mathematics. However, students' mathematical critical thinking abilities vary due to several influencing factors. The relationship between intrapersonal intelligence and critical thinking is significant, as they complement each other in shaping students' cognitive development. Intrapersonal intelligence positively impacts students' thinking processes, and when combined with scientific critical thinking, it fosters a deeper understanding of concepts. Rejeki (2020) emphasized that intrapersonal intelligence and critical thinking must be nurtured together to develop theoretical generalizations and enhance students' attitudes, behaviors, and environmental awareness.

Intrapersonal and interpersonal intelligence are part of Gardner’s theory of multiple intelligences, which includes visual-spatial, linguistic-verbal, logical-mathematical, kinesthetic-physical, musical, interpersonal, intrapersonal, and naturalistic intelligences. Rubio in Perez (2014), defined intrapersonal intelligence as the ability to understand oneself, recognize emotions, assess personal strengths and weaknesses, and resolve internal conflicts affecting psychological balance. According to Amstrong (2009) intrapersonal intelligence refers to an individual's self-awareness and the ability to adapt their actions based on that awareness. It involves having a clear understanding of oneself, including strengths and weaknesses, as well as being mindful of one's emotions, intentions, motivations, temperament, and desires. Additionally, this intelligence encompasses self-discipline, self-comprehension, and a strong sense of self-worth.

Besides intrapersonal intelligence, there is interpersonal intelligence. Interpersonal intelligence is rooted in social intelligence, which refers to an individual's ability to build and maintain social relationships (Gardner, 2006). Advani and Hema (2016) defined interpersonal intelligence as the ability to understand and interact effectively with others. In this study, interpersonal intelligence is measured by students' ability to respond to information, comprehend messages, and establish social relationships. There are four key aspects of interpersonal intelligence, namely communication, empathy, cooperation, and conflict resolution.

Hayes (1999) described interpersonal intelligence as goal-directed behavior in face-to-face interactions that facilitates desired outcomes. In educational settings, interactions between teachers and students, as well as among peers, play a crucial role in supporting cognitive development. Gillies in Hidayati (2017) outlined four key interpersonal skills in classroom learning: (a) active listening, (b) freely expressing ideas, (c) taking responsibility for one's actions, and (d) providing constructive criticism. These interpersonal skills are required for students to collaborate effectively and improve their understanding of mathematical concepts.

However, research by Rivai, et. al. (2021) showed that not all students with high interpersonal intelligence exhibit strong communication skills in solving mathematical problems. Some students struggle to represent real-life objects and situations as mathematical models, and they face difficulties arise in understanding and interpreting mathematical representations, which can hinder problem-solving. Similarly, Sarwi, et. al., (2021) found a positive but moderate correlation between critical thinking ability and interpersonal intelligence.

Based on the this study, aims to examine how students' intrapersonal and interpersonal intelligence influence their critical thinking and mathematical communication skills. Few studies have examined this topic among junior high school students in Yogyakarta. A deeper understanding of the impact of these intelligences on mathematical abilities can contribute to developing more effective instructional strategies. Given the limited research in this area, particularly at the secondary level, this study seeks to explore the relationship between intrapersonal and interpersonal intelligence and critical thinking and mathematical communication skills among junior high school students in Yogyakarta City.

2. Method

This study employs a survey research design with a quantitative approach, collecting data through tests and questionnaires. It addresses research questions regarding the critical thinking and mathematical communication skills, particularly students' intrapersonal and interpesonal intelligence in public junior high school students in Yogyakarta City. Twelve public junior high schools were selected for this study based on their most recent Regional Education Standardization Assessment results.

The population of this study consists of 3,442 grade VIII students from 16 public junior high schools in Yogyakarta City during the 2022/2023 academic year. This study's sampling technique was proportionate stratified random sampling, which enrolled 368 students. Data collection methods include both tests and non-tests. The tests measure students' critical thinking and mathematical communication skills, while non-tests aim to capture students' thought processes when solving given problems. Questionnaires were applied to assess students' intrapersonal and interpersonal intelligence.

The test instrument is in a written description (essay) format, consisting of three questions developed based on critical thinking indicators from Facione (2011) and mathematical communication indicators from Sumarmo (2012). The indicators of critical thinking are Interpretation, Analysis, Evaluation, Inference, and Explanation. Mathematical communication ability is evaluated using four indicators: (I1) expressing mathematical ideas in the form of mathematical concepts, (I2) representing mathematical ideas through diagrams, images, or graphs, (I3) translating ideas and situations from diagrams, graphs, or images into mathematical concepts, and (I4) modeling contextual problems into mathematical concepts.

The questionnaire used in this study contains 30 statements, 15 of which relate to intrapersonal intelligence and the other 15 to interpersonal intelligence. These 30 statements are divided into 15 positive and 15 negative items. The intrapersonal and interpersonal intelligence indicators are adapted from Wijayanti (2015) and Paradita et al., (2019). The questionnaire is a checklist format containing statements about students' intrapersonal and interpersonal intelligence. The scale used in this study is a Likert scale with five response options from always (5) to never (1).

The content validity of the intrapersonal and interpersonal intelligence questionnaire was evaluated by three experts in the field of mathematics. The validity calculation for the questionnaire resulted in a moderate decision. The reliability coefficient for the intrapersonal and interpersonal intelligence questionnaire, calculated using Cronbach's alpha, was $\alpha=0.8$. This indicates that the questionnaire is reliable (Ebel & Frisbie, 1991).

The data analysis techniques used in this study are descriptive statistics and inferential statistics. Descriptive statistics will focus on students' intrapersonal and interpersonal intelligence, critical thinking, and mathematical communication skills. It will also examine the effects of intrapersonal and interpersonal intelligence on both critical thinking and mathematical communication skills. The values for critical thinking

ability, mathematical communication ability, and intrapersonal and interpersonal intelligence will be categorized using intervals adapted from Hopkins & Antes (1990). The following presents the maximum and minimum values for each test instrument.

Table 1. Ideal Scores of Variables

Variables	Maximum Score	Minimum Score	Mean ($\bar{x}_i$)	Standard Deviation
Critical Thinking	69.62	36.79	53.21	5.47
Mathematical Communication	70.94	32.91	51.93	6.33
Intrapersonal and Interpersonal Intelligence	79.52	0.05	39.79	13.24

This study contains two dependent variables, namely critical thinking ability (Y_1) and mathematical communication ability (Y_2) and two independent variables, namely intrapersonal intelligence (X_1) and interpersonal intelligence (X_2). Before doing the regression analysis test, it is necessary to test the assumptions first, namely: Normality test, linearity test, multicollinearity test, and heteroscedasticity test. By conducting this assumption test, we can ensure that the regression model used meets the necessary conditions to produce valid and reliable estimates.

The normality test results show that the *p*-value for variable Y_1 is 0.138 and for Y_2 is 0.478, both of which are greater than the significance level. Thus, H_0 is accepted for both variables, which means that the samples come from a normally distributed population. The linearity test showed that the *p*-value for the critical thinking variable on intrapersonal and interpersonal intelligence was 0.16, and for the mathematical communication variable on intrapersonal and interpersonal intelligence was 0.11, both greater than 0.05. Therefore, H_0 is accepted, indicating a linear relationship between the independent and dependent variables. Multicollinearity calculation shows the VIF value of intrapersonal and interpersonal intelligence variables is 1.53 (VIF < 10) and the tolerance is 0.65 (> 0.10), so there is no multicollinearity. Heteroscedasticity calculations showed significance values of 0.943 and 0.825, both more than 0.05, indicating the absence of heteroscedasticity symptoms in the regression model between critical thinking and mathematical communication skills with intrapersonal and interpersonal intelligence.

3. Result and Discussion

This sub-chapter presents the research findings derived from the students' intrapersonal and interpersonal intelligence questionnaires, as well as the test results assessing their critical thinking and mathematical communication skills. The description focuses on students' intrapersonal and interpersonal intelligence, their critical thinking and mathematical communication abilities, and the influence of intrapersonal and interpersonal intelligence on both critical thinking skills and mathematical communication skills. The percentage of critical thinking skills among students in public junior high schools in Yogyakarta City, categorized accordingly, is shown in Table 2 below:

Table 2. Percentage of Students' Critical Thinking Ability

Category	Score Interval	f	Percentage (%)
Very High	$X > 61.4$	67	18%
High	$55.9 < X \leq 61.4$	51	14%
Moderate	$50.5 < X \leq 55.9$	52	14%
Low	$45 < X \leq 50.5$	70	19%
Very Low	$X \leq 46.5$	128	35%

Based on Table 2, it showed that the mathematical critical thinking skills of junior high school students in Yogyakarta City are predominantly in the very low category. However, 32% of students demonstrate mathematical critical thinking skills in the high or very high categories. The results of the analysis of mathematical critical thinking skills among junior high school students, categorized by aspects of critical thinking, can be seen in Table 3 below:

Table 3. Analysis Results Based on Critical Thinking Ability Indicators

No	Aspects of Critical Thinking	Question No.	Average Score	Category
1	Interpretation	1	48.7	Moderate
2	Analysis			
3	Evaluation	2	56.6	Low
4	Inference	3	50	Very Low
5	Explanation			

Based on the information in Table 3, it can be seen that for the aspects of interpretation which involves clarifying a problem clearly, and the aspect analysis, which involves identifying relevant and irrelevant statements—both have an average value of 49.9, falling within the moderate category. Item number 2, which addresses the evaluation aspect (assessing statements, arguments, or conclusions related to the problem), has an average of 50, placing it in the low category. Similarly, item number 3, which addresses the aspects of inference and explanation, with indicators such as drawing conclusions based on information and providing reasons supported by concepts and evidence, also has an average of 50 in the low category.

This is in line with Azizi (2020), where five students who were research subjects were unable to meet all indicators of critical thinking skills. These students were able to fulfill only one or two indicators, indicating that they still lack mastery in these skills. This may be due to learning activities that have not provided opportunities for students to engage in critical thinking, as well as the lack of habitual practice with non-routine problems, leading students to find math problems in trigonometry particularly challenging. Teacher can provide daily context problem in the learning activity and give student proper scaffolding to promote students' critical thinking (Manaf et al., 2024).

The percentage of mathematical communication skills of students in public junior high schools in Yogyakarta, categorized accordingly, can be seen in Table 4 below:

Table 4. Percentage of Students' Mathematical Communication Ability

Category	Score Interval	f	Percentage (%)
Very High	$X > 61.4$	52	14%
High	$55.1 < X \leq 61.4$	65	18%
Moderate	$48.8 < X \leq 55.1$	67	18%
Low	$42.4 < X \leq 48.8$	112	30%
Very Low	$X \leq 42.4$	72	20%

Based on Table 4, it can be seen that the mathematical communication skills of junior high school students in Yogyakarta City from this research sample are predominantly in the low category. However, 32% of students demonstrate mathematical communication skills in the high or very high categories. The results of the analysis of mathematical communication skills among junior high school students, based on these indicators, are presented in Table 5 below.

Table 5. Results of Analysis Based on Indicators of Mathematical Communication Ability

No	Indicator of Mathematical Communication	Question No.	Average Score	Category
1	Indicator 1	1	50	Very High
2	Indicator 2	2	49.9	Low
3	Indicator 3	3	50	Low
4	Indicator 4			

Based on Table 5, Indicator 1 of mathematical communication ability expressing mathematical ideas in the form of mathematical concepts is categorized as high, indicating that students are able to effectively express their mathematical ideas.

The intrapersonal and interpersonal intelligence questionnaires were administered to students, consisting of 30 statement items with a scoring range of 1 to 5. This results in a total score range of 30 to 150 for both intrapersonal and interpersonal intelligence. The aspects used to measure intrapersonal intelligence include self-recognition, knowing one's desires, and understanding what is important. In contrast, interpersonal intelligence is measured in terms of social activity, interaction, and empathy. Each aspect of intrapersonal and interpersonal intelligence will be further divided classified into specific indicators. Table 6 shows the percentage of intrapersonal and interpersonal intelligence among students in Yogyakarta City's public junior high schools, categorized as follows:

Table 6. Percentage of Intrapersonal and Interpersonal Intelligence

Category	Score Interval	f	Percentage (%)
Very High	$X > 64.4$	58	16%
High	$53.7 < X \leq 64.4$	181	49%
Moderate	$43.0 < X \leq 53.7$	112	30%
Low	$32.2 < X \leq 43.0$	11	3%
Very Low	$X \leq 32.2$	6	2%

Based on Table 6, 181 out of 368 students scored high in intrapersonal and interpersonal intelligence, while 6 out of 368 scored very low. It indicates that the intrapersonal and interpersonal intelligence of public junior high school students in Yogyakarta City in this research sample is predominantly in the high category, with 49% of respondents (181 students) falling into this category. The least represented category is the very low category, with only 6 students scoring in this range.

3.1 Intrapersonal and Interpersonal Intelligence on Students' Critical Thinking Ability

This study investigated the combined effect of intrapersonal and interpersonal intelligence on the critical thinking skills of public junior high school students in Yogyakarta City. Testing the simultaneous hypothesis of the study was carried out using the F test. The summary of the Multiple Linear Regression Test results is shown in Figure 1 as follows:

```
Residual standard error: 10.03 on 364 degrees of freedom
Multiple R-squared:  0.001681,  Adjusted R-squared:  -0.003804
F-statistic: 0.3065 on 2 and 364 DF,  p-value: 0.7362
```

Figure 1. *F*-test Output Critical Thinking Based on Intrapersonal and Interpersonal Intelligence

Based on the results presented in Figure 1, the *p*-value is 0.736, thus H_0 is accepted ($p>0.05$). This indicates that there is no significant effect of intrapersonal and interpersonal intelligence on the critical thinking skills of public junior high school students in Yogyakarta City. This conclusion is supported by the $R^2 = 0.0016$, which shows that only 0.16% of the variance in students' critical thinking skills can be explained by intrapersonal and interpersonal intelligence. Since H_0 is accepted, further analysis through partial testing is not conducted.

3.2 Intrapersonal and Interpersonal Intelligence on Students' Mathematical Communication Ability

This study examined the combined effect of intrapersonal and interpersonal intelligence on the mathematical communication skills of students in public junior high schools in Yogyakarta City. Simultaneous hypothesis testing was performed using the *F*-test. A summary of the results from the multiple linear regression analysis is presented in Figure 2 below:

```
Residual standard error: 9.738 on 364 degrees of freedom
Multiple R-squared:  0.05695,   Adjusted R-squared:  0.05177
F-statistic: 10.99 on 2 and 364 DF,  p-value: 2.317e-05
```

Figure 2. *F*-test Output Mathematical Communication Based on Intrapersonal and Interpersonal Intelligence

Based on the results presented in Figure 2, the *p*-value is 0.000, indicating that H_0 is rejected ($p<0.05$). It suggests that, simultaneously, intrapersonal and interpersonal intelligence significantly influence the mathematical communication skills of students in public junior high schools in Yogyakarta City. Furthermore, the R^2 value is 0.0569 indicated that intrapersonal and interpersonal intelligence account for 5.7% of the variation in the mathematical communication skills of students in public junior high schools in Yogyakarta City, while the remaining variance is explained by other variables not addressed in this study.

```
Call:
lm(formula = KM ~ INTRA + INTER, data = RBB)

Residuals:
    Min      1Q  Median      3Q     Max
-21.134  -6.314  -1.272   7.776  23.258

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 38.51582    2.90112  13.276  < 2e-16 ***
INTRA       -0.02154    0.06292  -0.342    0.732
INTER        0.25068    0.06292   3.984 8.19e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 3. Multivariate Regression Output of Mathematical Communication

Based on Figure 3, the interpretation of the multiple regression equation is as follows:

$$\hat{Y}_2 = 38.51 - 0.02X_1 + 0.25X_2 \quad (1)$$

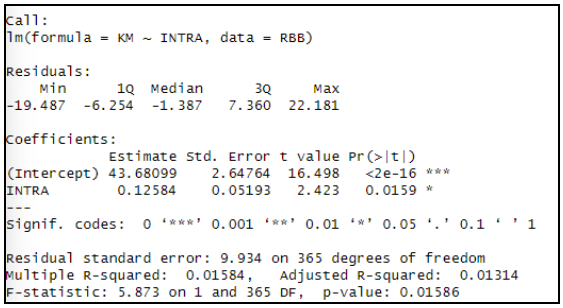
Based on the regression equation, the mathematical communication ability, in the absence of any influence from intrapersonal and interpersonal intelligence, is 38.21. For each unit increase in intrapersonal intelligence (X_1), while holding interpersonal intelligence (X_2) constant, students' mathematical communication skills decrease by 0.02. This negative effect is attributed to the relatively low levels of intrapersonal intelligence, which influence the regression results. On the other hand, for each unit increase in interpersonal intelligence (X_2), while holding intrapersonal intelligence (X_1) constant, students' mathematical communication skills increase by 0.25.

Partial Test (T Test)

Based on Figure 3, the regression coefficient for intrapersonal intelligence resulted in a *p*-value of 0.732. Since 0.732 > 0.05, H_0 is accepted, indicating that there is no significant influence of intrapersonal intelligence on the mathematical communication skills of public junior high school students in Yogyakarta City. In contrast, the regression coefficient for interpersonal intelligence yielded a *p*-value of 0.000. Since 0.000 < 0.05, H_0 is rejected, suggesting that there is a significant influence of interpersonal intelligence on the mathematical communication skills of these students. Given that only interpersonal intelligence has a significant effect on mathematical communication skills, the simple linear regression equation can be expressed as follows:

$$\hat{Y}_2 = 38{,}51 + 0{,}25X_2 \quad (2)$$

Based on the regression equation, the mathematical communication ability, in the absence of any influence from interpersonal intelligence, is 38.51. According to the regression coefficient, for each unit increase in interpersonal intelligence (X_2), students' mathematical communication skills increase by 0.25. After conducting a partial test, it was found that intrapersonal intelligence does not have a significant effect on students' mathematical communication skills. Therefore, further analysis was performed using simple linear regression. The effect of intrapersonal intelligence on students' mathematical communication skills is presented in Figure 4 below:



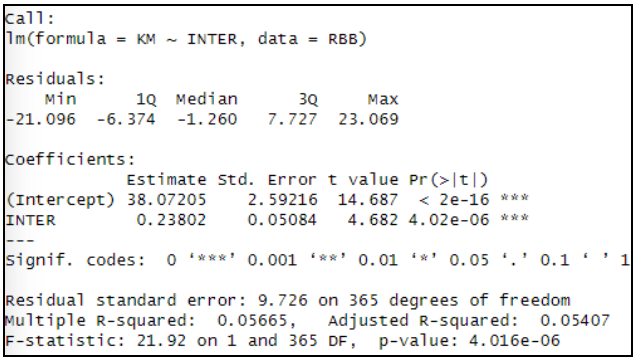
```
Call:
lm(formula = KM ~ INTRA, data = RBB)

Residuals:
    Min      1Q  Median      3Q     Max
-19.487  -6.254  -1.387   7.360  22.181

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 43.68099    2.64764  16.498   <2e-16 ***
INTRA        0.12584    0.05193   2.423   0.0159 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 9.934 on 365 degrees of freedom
Multiple R-squared:  0.01584,   Adjusted R-squared:  0.01314
F-statistic: 5.873 on 1 and 365 DF,  p-value: 0.01586
```

Figure 4. Regression Output of Mathematical Communication Based on Intrapersonal Intelligence

Based on the results presented in Figure 4, the *p*-value is 0.019. Since 0.019 < 0.05, H_0 is rejected, indicating a significant effect of intrapersonal intelligence on the mathematical communication skills of public junior high school students in Yogyakarta City. However, the influence is relatively small, accounting for only 1.59% of the variance, as reflected by the multiple R^2 value of 0.1584. The simple linear regression equation based on these results is as follows:

$$\hat{Y}_2 = 43{,}68099 + 0{,}12584X_1 \quad (3)$$

Based on the regression equation, the mathematical communication ability, in the absence of any influence from intrapersonal intelligence, is 43.68. According to the regression coefficient, for each unit increase in intrapersonal intelligence (*X1*), students' mathematical communication skills increase by 0.12. The results from the multiple linear regression analysis in the partial test section reveal a different outcome compared to the simple linear regression analysis regarding the effect of intrapersonal intelligence on students' mathematical communication skills. The calculations related to the effect of interpersonal intelligence on students' mathematical communication skills are presented in Figure 5 below:



```
Call:
lm(formula = KM ~ INTER, data = RBB)

Residuals:
    Min      1Q  Median      3Q     Max
-21.096  -6.374  -1.260   7.727  23.069

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 38.07205    2.59216  14.687  < 2e-16 ***
INTER        0.23802    0.05084   4.682 4.02e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 9.726 on 365 degrees of freedom
Multiple R-squared:  0.05665,   Adjusted R-squared:  0.05407
F-statistic: 21.92 on 1 and 365 DF,  p-value: 4.016e-06
```

Figure 5. Regression Output of Mathematical Communication Based on Interpersonal Intelligence

Based on Figure 5, the *p*-value is 0.000. Since 0.000 < 0.05, H_0 is rejected, indicating that there is a significant effect of interpersonal intelligence on the mathematical communication skills of public junior high school students in Yogyakarta City. However, this effect accounts for only 5.67% of the variance, as indicated by the multiple R^2 value of 0.0566. This finding is consistent with the research conducted by Putri et al., (2022), which found that interpersonal intelligence positively and significantly influences students' mathematical communication skills, contributing 9.3%. The simple linear regression equation derived from these results is as follows:

$$\hat{Y}_2 = 38{,}072 + 0{,}238X_2 \quad (4)$$

Based on the obtained regression equation, the mathematical communication ability, without the influence of interpersonal intelligence, is 38.072. According to the regression coefficient, for each unit increase in interpersonal intelligence (*X2*), students' mathematical communication skills increase by 0.23. The results from the multiple linear regression analysis in the partial test section regarding the effect of interpersonal intelligence on students' mathematical communication skills align with the findings of the simple linear regression analysis.

The analysis reveals that interpersonal intelligence has a more significant effect on the mathematical communication skills of students in Yogyakarta City public junior high schools, contributing 5.67%,

compared to intrapersonal intelligence, which only accounts for 1.59% of the variance in students' mathematical communication skills.

Students' critical thinking skills were assessed based on a critical thinking skills test consisting of three questions on the material of the system of linear equations in two variables, which is part of the seventh-grade curriculum. Each question required students to outline their solution process and provide a conclusion. The average critical thinking score for eighth-grade students in Yogyakarta City was 50, placing it within the moderate category. This aligns with the findings of Danaryanti (2018), which indicated that students' critical thinking skills were in the moderate category. Similarly, Afifah (2020) research reported that the critical thinking abilities of junior high school students were also in the moderate category, with a total percentage of 36.84%. An overview of students' critical thinking skills in mathematics can be seen based on the predetermined critical thinking indicators. The percentage of student success in each indicator is as follows:

a. *Interpretation*

Among all students, approximately 49.9% were able to adequately answer items that represent the interpretation indicator. This suggests that nearly half of the students are capable of understanding and clearly expressing the meaning of clarifying a problem.

b. *Analysis*

Approximately 49.9% of students answered correctly the items representing the analysis indicator. This implies that nearly half of the students can understand and identify which statements are relevant and irrelevant to the problem at hand.

c. *Evaluation*

The evaluation indicator in the critical thinking skills instrument is represented by question item number 2. Around 50% of students answered this question correctly. This indicates that nearly half of the students can comprehend and assess the statement, argument, or conclusion related to the problem. For this aspect, eighth-grade junior high school students in Yogyakarta City fall within the low category.

d. *Inference*

The inference indicator in the critical thinking skills instrument is represented by item number 1. Around 50% of students answered this question correctly, meaning that nearly half of the students can understand and draw conclusions based on the information provided. This aspect places eighth-grade junior high school students in Yogyakarta City within the low category.

e. *Explanation*

The explanation indicator is represented by item number 1 in the critical thinking skills instrument. Approximately 50% of students answered correctly, suggesting that half of the students can understand, explain, and provide appropriate justifications based on concepts and evidence. Similar to the previous indicators, this aspect places eighth-grade students in Yogyakarta City in the low category.

Students' mathematical communication skills were assessed through a set of three questions focusing on the system of linear equations in two variables, which is part of the seventh-grade curriculum. For each question, Students were required to show their solution process and provide a conclusion on each question. The average score for mathematical communication skills of eighth-grade students in Yogyakarta City was 50, which falls under the moderate category. The indicators used to assess students' mathematical communication skills are as follows:

- Expressing mathematical ideas in the form of mathematical concepts, as illustrated by item number 1.
- Representing mathematical ideas in the form of diagrams, images, or graphs, as indicated by item number 2.
- Expressing ideas and situations from diagrams, graphs, or images into mathematical concepts, as represented by item number 3.
- Modeling contextual problems into mathematical concepts, also represented by item number 3.

An overview of students' mathematical communication skills based on these indicators is provided below:

- Expressing mathematical ideas in the form of mathematical concepts (Item 1): This ability is classified in the very high category, with an average score of 50.
- Expressing mathematical ideas in the form of diagrams, images, or graphs (Item 2): This ability is classified in the low category, with an average score of 49.9.
- Representing ideas and situations from diagrams, graphs, or images into mathematical concepts (Item 3): This ability is classified in the very high category, with an average score of 50.
- Modeling contextual problems into mathematical concepts (Item 3): This ability is also classified in the very high category, with an average score of 50.

The average score for intrapersonal and interpersonal intelligence among eighth-grade students in Yogyakarta City is 49.57, falling within the high category. An overview of the intrapersonal and interpersonal intelligence of eighth-grade students in Yogyakarta City can be seen below based on the defined aspects of these abilities:

a. Social Activity Aspect (Interpersonal Intelligence)

This aspect consists of two indicators: (1) Caring for others and helping each other in difficult situations (represented by statement items 1 and 9), and (2) Participating and taking responsibility in discussions and group activities (represented by statement items 2 and 10). For these four items, the average score of all eighth-grade students in Yogyakarta City is 14 out of 20.

b. Interaction Aspect (Interpersonal Intelligence)

This aspect includes three indicators: (1) Communication (represented by statement items 11 and 3), (2) Working as part of a study group (represented by statement items 12 and 4), and (3) Enjoying group activities (represented by statement items 5 and 13). For these six items, the average score of all students is 19 out of 30.

c. Empathy Aspect (Interpersonal Intelligence)

This aspect consists of three indicators: (1) Understanding the situation of others (represented by statement items 6 and 14), (2) Caring for others (represented by statement items 7 and 15), and (3) Feeling what others feel (represented by statement items 8 and 16). The average score for these six items is 22 out of 30.

d. Self-recognition Aspect (Intrapersonal Intelligence)

This aspect includes three indicators: (1) Understanding one's own feelings (represented by statement items 17 and 24), (2) Expressing thoughts, feelings, opinions, and beliefs (represented by statement items 18 and 25), and (3) Having a high self-assessment (represented by statement items 19 and 26). The average score for these six items is 17 out of 30.

e. Knowing What One Wants Aspect (Intrapersonal Intelligence)

This aspect consists of two indicators: (1) Having self-awareness about personal goals and intentions (represented by statement items 20 and 27), and (2) Maximizing one's potential (represented by statement items 18 and 25). The average score for these four items is 14 out of 20.

f. Knowing What Is Important Aspect (Intrapersonal Intelligence)

This aspect consists of two indicators: (1) Self-motivation (represented by statement items 29 and 22), and (2) Having an independent attitude (represented by statement items 23 and 30). The average score for these four items is 13 out of 20.

3.3 The Effect of Students' Intrapersonal and Interpersonal Intelligence on Students' Critical Thinking Ability

Regression analysis results indicate that intrapersonal and interpersonal intelligence simultaneously do not have a significant effect on the critical thinking ability of junior high school students in Yogyakarta City. Students with high levels of intrapersonal and interpersonal intelligence tend to have lower critical thinking skills, suggesting the presence of other dominant factors influencing their critical thinking ability. Conversely, students with low intrapersonal and interpersonal intelligence tend to demonstrate moderate-level critical thinking skills. The regression analysis indicates that intrapersonal and interpersonal intelligence contribute only 0.16% to variations in students' critical thinking abilities, while the remaining variance is influenced by other factors, such as learning models.

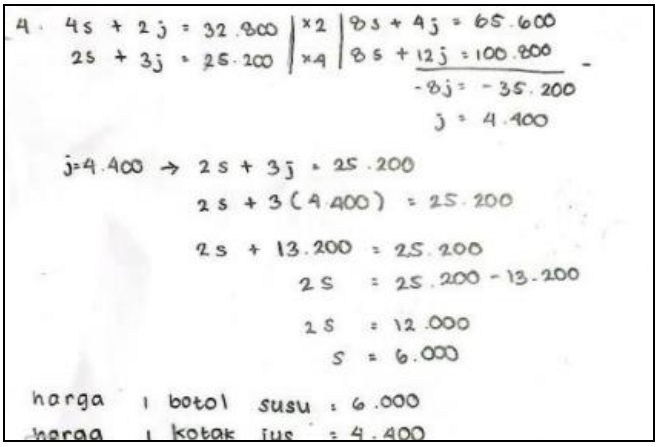


Figure 6. Example Work of Moderate Critical Thinking and Low Intelligence Student

Figure 6 presents the work of a student with moderate critical thinking ability and low intrapersonal and interpersonal intelligence. The student's responses demonstrate a structured and accurate understanding, as they directly noted the given information from the problem without explicitly writing "given" and "asked" sections, yet they still provided a description or conclusion of their results. These findings align with Daniyati and Sugiman (2015) who stated that intrapersonal intelligence is a component in shaping one's critical thinking patterns, although the reason why their critical thinking is not fully optimized remains unclear. Intrapersonal intelligence also contributes to positive learning behavior, while learning efficacy influences the enhancement of students' critical thinking skills. However, intrapersonal and interpersonal intelligence only account for 0.16% of students' critical thinking ability, indicating that other factors play a more significant role in determining their level of critical thinking.

3.4 The Effect of Students' Intrapersonal and Interpersonal Intelligence on Students' Mathematical Communication Ability

The results of the regression analysis indicate that both intrapersonal and interpersonal intelligence significantly influence students' mathematical communication skills. This finding aligns with research by Putri, et. al. (2022), which demonstrated a significant positive effect of interpersonal intelligence on students' mathematical communication skills, contributing 9.3%. The analysis further reveals that students with high levels of intrapersonal and interpersonal intelligence generally exhibit superior mathematical communication skills. However, some students with high intelligence still display low communication skills, suggesting the presence of additional factors influencing mathematical communication. The regression analysis indicates that intrapersonal and interpersonal intelligence account for only 5.7% of the variation in mathematical communication skills, with the remainder likely attributed to other factors.

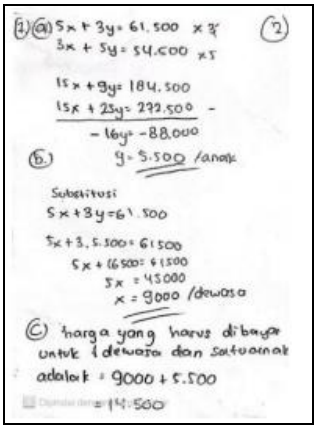


Figure 7. Example Work of Moderate Critical Thinking and High Intelligence Student

Figure 7 shows the result of a student's work with moderate mathematical communication skills, as well as high intrapersonal and interpersonal intelligence. In their response, the student correctly writes all the results of the given problem. In point (a), the student systematically writes the information provided in the problem

in a clear and accurate sequence. However, the student does not include a description or conclusion of the results obtained, nor do they list the initial information from the problem, such as the sections ‘given’ and ‘asked’. This aligns with the research conducted by Rivai, et. al. (2021), which states that not all students with high interpersonal intelligence possess good mathematical communication skills. Some students struggle to express the real objects, situations, and daily occurrences into mathematical models, as well as to understand mathematical models to solve math problems. Tyaningsih, et. al. (2022) also observed that students with low intrapersonal intelligence and high interpersonal intelligence tend to face difficulties in selecting appropriate problem-solving strategies and writing clear solutions, although they excel at articulating their thoughts orally.

Mathematical communication, a process of social interaction, involves the exchange of mathematical information, ideas, and understanding. Interpersonal intelligence, which is closely linked to social activities and communication skills, plays a pivotal role in this process. Dewi (2019) emphasized that interpersonal intelligence is crucial for learning mathematics, as it encompasses more than just the application of logic or calculation. Additionally, Marfiah (2020) found that intrapersonal intelligence significantly impacts students' mathematical communication skills in algebraic topics. Students with high intrapersonal intelligence tend to perform better in mathematical communication, as they are more adept at understanding, managing, and controlling their own emotions and behaviors.

In this study, interpersonal intelligence refers to the ability to understand and interact effectively with others within the context of mathematics. Ulfatun (2019) demonstrated that both intrapersonal and interpersonal intelligence jointly influence students' mathematical communication skills in solving statistical problems. Furthermore, Putri, et. al. (2022) confirmed a positive relationship between interpersonal intelligence indicators and mathematical communication skills, where interpersonal intelligence enhances students' ability to communicate mathematically. Mathematical communication involves the exchange of mathematical concepts, ideas, and reasoning between individuals, and interpersonal intelligence is a critical factor in facilitating this exchange by explaining algorithms and expressing mathematical ideas in both language and symbols.

4. Conclusion

Based on the research findings, the following conclusions can be drawn: (1) The public junior high school students in Yogyakarta City within the sample predominantly exhibit low critical thinking skills, with 54% falling within this category. Additionally, students' mathematical communication skills are evenly distributed between high and low categories, each comprising 50%. (2) The majority of students (65%) exhibit high levels of intrapersonal and interpersonal intelligence. (3) Among students with low intrapersonal and interpersonal intelligence, 27% demonstrate moderate-level critical thinking skills, while their mathematical communication skills are predominantly categorized as low. Conversely, students with very high intrapersonal and interpersonal intelligence tend to show low critical thinking skills (28%), while their mathematical communication skills are generally high (28%). (4) There is no significant effect of intrapersonal and interpersonal intelligence on students' critical thinking skills. However, these intelligences have a significant impact on students' mathematical communication skills when considered together.

A limitation of this study is the inability to fully control extraneous factors, such as student honesty, physical health, and psychological conditions, during the administration of the critical thinking and mathematical communication skills tests, as well as the intrapersonal and interpersonal intelligence questionnaire. The findings of this study highlight the need for further research focusing on the relationship between students' critical thinking skills, mathematical communication abilities, and their intrapersonal and interpersonal intelligence, particularly in junior high schools in Yogyakarta City. Furthermore, it is important to foster students’ intrapersonal and interpersonal intelligence through learning activity that promote students’ interaction.

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