Assessing students' mathematical reasoning in problem-based learning: a gender perspective

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Article Info

Article history:

Received Dec 12, 2023
Revised Apr 3, 2024
Accepted May 7, 2024

Keywords:

Gender
Mathematical reasoning
Mixed method
Problem-based learning
Problem-solving

ABSTRACT

Mathematical reasoning (MR) in problem-solving is still relatively low, but students need it. Previous studies have shown that problem-based learning (PBL) can improve MR. Meanwhile, differences in MR are also influenced by gender. This study assesses MR quantitatively and qualitatively by reviewing gender differences when given PBL intervention. The research participants involved were fifth-grade primary students. The sampling techniques used were convenience and purposive sampling. This study design uses an explanatory sequential mixed method with quantitative data collection followed by qualitative data. Instruments like MR tests, interview guides, and questionnaires were used to collect data. Analysis techniques used for quantitative data are descriptive statistics, n-gain, and Wilcoxon signed-rank test, while qualitative data is thematic analysis. The study found that quantitatively, PBL significantly affects the MR of students with different gender perspectives. Meanwhile, qualitative findings in MR varied among students of different genders (masculine, feminine, and neutral) in the implication of PBL. Another finding is that students' MR is inadequate in generalizing the statement. The study results provide comprehensive findings regarding the differences in MR of students with gender differences in the implications of PBL, which can contribute practical, theoretical, or methodological to teachers, practitioners, researchers, and scholarship.

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1. INTRODUCTION

Mathematical reasoning (MR) is known as logical thinking in problem-solving that cannot be solved directly [1]–[3]. MR can help beginner students solve problems [4]. From the competence achievement point of view, improving MR for problem-solving is needed for students to achieve adequate learning outcomes in learning mathematics [5]. Achieving MR for problem-solving includes overcoming active interaction and thinking skills in learning mathematics activities [6]. In this, teachers must develop MR at the primary school level. This is because the opportunities teachers give students in learning can improve early for the development of reasoning in problem-solving [4].

The Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) studies reveal that students' MR in Indonesia is still relatively low. This shows that reasoning is an important thing that needs attention [7]. The PISA results also showed that students' MR in Indonesia is still relatively low. This is indicated by the decline in the mean mathematics score from 386 to 379 [8]. Based on the TIMSS in 2015, students' MR level was ranked 44 out of 49 countries [9]. Thus, student problem-solving skills that require MR can also be troubled.

Previous researchers have shown that problem-based learning (PBL) improves mathematical reasoning skills [10], [11]. Lapuz [10] argued that through PBL, MR can improve because students acquire knowledge through unstructured solutions. PBL positively improves MR because it solves the problem-solving strategies teachers encounter in learning [11]. Based on the study's results, MR can be enhanced by implication PBL [12], [13]. In addition, PBL is a learning that requires students to think at a higher level through MR [14], [15]. Therefore, PBL can be used as a learning solution to correct students' inadequate MR.

Problem-based learning is not always a sufficient solution to improve students' MR comprehensively. There is an opinion that gender perspective is vital in MR [16]. Gender is a social construction that differentiates the psychic functions of men and women in terms of attitudes, emotions, and social actions that develop in society [17], [18]. Internal factors affect the reasoning process, namely gender differences that cause differences in reasoning ability and learning results [19]. The analysis of MR from a gender perspective is considered essential because the Indonesian government sets gender issues in the sustainable development program in education, especially in mathematics, so that it can improve reasoning skills and improve student learning results [20], [21]. Thus, a gender perspective is needed in the implication of PBL to assess students' MR better.

In the last few periods, the available studies still discuss MR by reviewing gender perspective but have not assessed it concerning PBL implementation. Several researchers stated that gender differences in men and women significantly affect students' MR. These gender differences may occur in aspects that include masculine, feminine, neutral, and androgynous [22], [23]. Leyva [24] suggested that more exploration is needed regarding masculine gender in students' mathematical achievement. In comparison, Pyfer [25] confirmed that feminine-gendered students can use instrumental and relational understanding through recognizing, forming, and confirming conjectures on a problem. Instrumental understanding is done by memorizing mathematical rules and algorithms without understanding their reasons. In contrast, relational understanding is done by understanding the problem and implementing problem-solving strategies appropriately and constructively.

Research on assessing students' MR in the implication of PBL by reviewing gender differences based on its aspects is still unavailable. Meanwhile, Smit *et al.* [26] emphasized the importance of assessing MR based on outcomes and processes. However, PBL can improve students' MR productively [10], [11]. Constructing learning processes that consider different gender perspectives can also result in different MRs [27]. Learning involving men and women in schools is expected to avoid gender gaps or biases [28]. This led us to assess the increase or decrease of students' MR towards PBL implementation as a product and to assess students' MR in terms of different gender perspectives as a process after PBL implementation. Therefore, the questions of this study lead to two things: i) is there a significant effect or difference in students' MR before and after PBL implementation?; and ii) how is students' MR descriptively viewed from different gender perspectives after PBL implementation? The research results through these two research questions are expected to provide practical benefits for educators: provide evidence and empirical ways that PBL implementation can increase or improve the MR of problematic students. In addition, it offers valuable information for policymakers to pay attention to gender differences concerning efforts to improve MR, especially through the implementation of PBL, so that differences in gender perspective are no longer seen as a biased review of learning.

2. METHOD

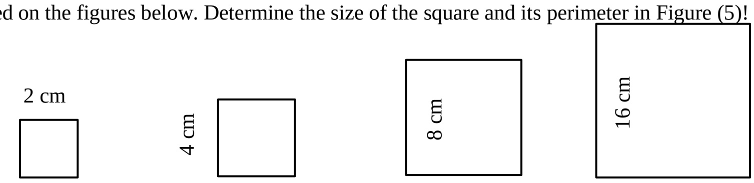
This study uses an explanatory sequential with a mixed-method approach. Explanatory sequential is a method that starts by collecting quantitative data and then continues with qualitative data to support the data processing process so that the study results can provide a comprehensive description. In this, a one-class experimental design was used to obtain quantitative data, followed by a narrative design to obtain qualitative data [29], [30]. A one-class experimental design was conducted by implementing PBL in one experimental class without a control group so that the effect or significance of differences in PBL implementation on students' MR could be determined. MR was assessed quantitatively before and after PBL implementation. Meanwhile, the narrative design was conducted after PBL implementation by assessing MR descriptively on students with different gender perspectives.

This study implemented PBL using five steps adapted from Arends [14], including: i) Orient students to the problem. In this step, the teacher conveys learning objectives, motivates students to learn, and presents authentic problems in the classroom; ii) Organize students for study, the teacher organizes students into small groups to have a more focused discussion to solve the problem. In this step, each group consists of 3-4 students; iii) Assist independent and group investigation, the teacher facilitates individual learning to understand the problem so that students can have alternative problem solutions. Furthermore, students in each group are asked to discuss the most appropriate alternative problem solutions with each other; iv) Develop and present artifacts and exhibits. Each group is motivated and encouraged to present the best problem-solving results to the class in this step. Students in each group take turns presenting the best-proposed problem-solving strategy and sequence of steps; v) Analyze and evaluate the problem-solving process. In this step, students from non-presenting groups are guided to be able to criticize and discuss the work of the group that has been presented.

The study participants were 21 fifth-grade primary school students at Sekolah Dasar Negeri Bulukandang 1 Prigen, East Java, Indonesia. In this study, sampling was conducted through two techniques, namely, convenience and purposive sampling. Convenience sampling was used to obtain quantitative data on students' MR with gender differences in PBL implementation. Convenience sampling was considered because this study emphasizes the existence of gender characteristics to assess students' MR. In addition, this study was conducted not to generalize the findings but to describe or assess students' MR in a small group of studies. The results of the gender presence study analysis resulted in four masculine, nine feminine, eight neutral, and no androgynous. In other words, there were three of the four supposed gender categories among all participants. Thus, the existence of three out of four gender categories was deemed sufficient to conduct a study on gender perspective involving 21 participants. Meanwhile, purposive sampling was used to obtain descriptive qualitative data about MR students by reviewing differences in gender categories after PBL was applied. One student each was taken randomly to represent students' MR in the masculine (MS), feminine (FS), and neutral (NS) categories, resulting in one subject in the MS, FS, and NS categories. A sample size of less than 30 is sufficient for one experimental class [31]. In addition, convenience sampling is emphasized not to generalize the findings but to describe or assess MR students in a small research group. Meanwhile, purposive sampling aims to find individuals or a group of individuals who represent specific characteristics.

The research instruments consisted of MR tests, interview guides, and gender questionnaires. MR test has four essay questions based on MR activities, each with an indicator for finding a relationship pattern, proposing a conjecture, verifying the statement's truth, and generalizing the statement [16], as presented in Table 1. Interview guides contain semi-structured questions about the depth of problem-solving in each MR activity, namely understanding the problem, planning the solution, carrying out the solution, and checking back [4]. The gender questionnaire has 30 items of the Bem Sex Roles Inventory (BSRI), which is adapted from Geldenhuys and Bosch [32]. The adaptation was made by changing the items that were previously in English to Indonesian. Each of the 10 items represents masculine, feminine, and neutral gender dimensions. The androgynous dimension occurs when the mean masculine and feminine scores are equal or balanced. The gender dimensions are shown in Table 2.

Table 1. Mathematical reasoning test

Indicators	Problems
Finding a relationship pattern	Based on the figures below. Determine the size of the square and its perimeter in Figure (5)!  Figure (1) Figure (2) Figure (3) Figure (4)
Proposing a conjecture	Mrs. Yanti has a rectangle-shaped land measuring 10 m×8 m. The land will be planted with 20 m² of spinach and 30 m² of kale. Is there any land left to plant corn? How much land is left?
Verifying the truth of the statement	Mr. Anton: Mom, is this square-shaped cloth for sale? Ms. Indah: Yes, this cloth is for sale, sir. Mr. Anton: What size is the cloth, Mom? Ms. Indah: Measures 2 m×2 m. The cloth price per m² is Rp. 12,000. Mr. Anton: So, the money that I have to pay is Rp. 48,000. Based on the dialog, try to prove whether Mr. Anton’s statement is true. Mr. Anton had to pay a total of Rp. 48,000.
Generalizing the statement	Unknown: Area of right triangle=84 m² The base of the right triangle=7 m Ask: What is the height of the right triangle? Explain how you found the height of the right triangle!

In data collection, there are two techniques: test and non-test. Test techniques are carried out by administering MR tests presented in pretest and posttest. The MR test is used to collect students' quantitative MR data. The final results regarding MR were assessed using the MR assessment rubric which has a Likert scale of 0-4 [16], as shown in Table 3. Meanwhile, non-test techniques were conducted by administering questionnaires and interviews. The questionnaire was used to collect quantitative data on students' gender categories obtained before the implementation of PBL. In this, gender is categorized into masculine, feminine, neutral, or androgynous on a scale of 1-7, namely, 1 (never true), 2 (usually not true), 3 (sometimes true), 4 (occasionally true), 5 (often true), 6 (usually true), and 7 (always true). Interviews were used to collect qualitative data regarding the depth of MR in a descriptive manner. In this case, the interview was conducted after obtaining students' MR data as the output of PBL implementation.

Table 2. Gender identity by 30 item Bem Sex Roles Inventory (BSRI)

Masculine	Feminine	Neutral
Assertive	Understanding	Conscientiousness
Leadership ability	Sympathetic	Moody
Dominant	Eager to soothe hurt feelings	Reliable
Strong personality	Sensitive to the needs of others	Jealous
Forceful	Compassionate	Conventional
Aggressive	Loves children	Tactful
Willingness to take a stand	Affectionate	Conceited
Independent	Gentle	Secretive
Defend own beliefs	Warm	Truthful
Willing to take risks	Tender	Adaptable

Table 3. Mathematical reasoning test scoring rubric

Indicators	Scales	Descriptions
Finding a relationship pattern	4	The pattern found is correct, the principles or concepts used are correct, and the arithmetic operation is precise
	3	The pattern found is correct, and the principles or concepts used are correct, but the arithmetic operation is less precise
	2	The pattern found is correct, but the principles or concepts used are wrong
	1	The pattern found is wrong
	0	No answer
Proposing a conjecture	4	The conjecture given is correct, there is a reason for the conjecture made, and it is precise
	3	The conjecture given is correct, there is a reason for the conjecture made, but it is less precise
	2	The conjecture given is correct, but there is no reason for the conjecture made
	1	The conjecture given is wrong
	0	No answer
Verifying the truth of the statement	4	The steps in the verification process are correct, the principles or concepts used are correct, and the arithmetic operation is precise
	3	The steps in the verification process are correct, the principles or concepts used are correct, but the arithmetic operation is less precise
	2	The steps in the verification process are correct, but the principles or concepts used are wrong
	1	The steps in the verification process are wrong or mostly wrong
	0	No answer
Generalizing the statement	4	Generalization is correct, and the process of generalizing is correct and precise
	3	Generalization is correct, but there is a slight error in the process of making a generalization
	2	Generalization is correct, but the process of generalizing is wrong or mostly wrong
	1	Generalization and the process of generalizing is wrong or mostly wrong
	0	No answer

Before being used, the MR test, interview guides, and gender questionnaire instruments were tested for validity and reliability. Validity was tested using Aiken V. Items that had a value equal to or less than 0.5 were revised again after testing. Meanwhile, reliability was tested with Cronbach's alpha with a value of more than 0.6. The reliability test results on the MR test, interview guides, and gender questionnaire instruments showed values of 0.87, 0.65, and 0.78. Thus, these instruments are declared valid and reliable, so instruments are suitable for use.

Data analysis was conducted using different techniques on quantitative and qualitative MR data. The data analysis techniques used were descriptive statistics, n-gain, and Wilcoxon signed-rank test in quantitative data. Descriptive statistics calculates the standard deviation and mean of MR in the pretest and posttest. Furthermore, n-gain was used to calculate the magnitude of the increase in students' MR based on pretest and posttest scores. The n-gain criteria are $g \leq 0.3$ (low), $0.3 < g \leq 0,7$ (medium), and $g > 0.7$ (high) [33]. The Wilcoxon signed-rank test is a non-parametric statistical test to measure the significance of differences between two groups of paired data with ordinal or interval scales but non-normal distribution. In addition, the Wilcoxon signed-rank test is an alternative test to the paired sample t-test. This is used to test the hypothesis "there is a significant difference in the mean scores of MR before and after PBL is applied." In qualitative data, the data analysis technique used is thematic analysis [27]. Thematic analysis was conducted by focusing MR data on its activities in finding a relationship pattern, proposing a conjecture, verifying the statement's truth, and generalizing the statement. In this, data that is inappropriate or does not support MR activities will be reduced or eliminated.

3. RESULTS AND DISCUSSION

3.1. Quantitative findings

Table 4 presents the results of descriptive analysis of students' MR obtained before (pretest) and after (posttest) PBL implementation. The mean pretest score was 5.81, while the mean posttest score was 11.52. In other words, the mean posttest score is higher than the pretest score. Thus, it can be interpreted that students' MR in the sample scope is higher after PBL implementation. On the other hand, Table 5 presents the results of the n-gain score test. Based on the calculation of the n-gain score test shows that the mean value of the n-gain score for student's MR is 0.5716 or 57.16%, which is in the medium category. This shows an increase in MR in the medium category due to PBL implementation.

Table 4. Description of pretest and posttest data

	N	Maximum	Minimum	Std. deviation	Mean
Pretest	21	9	4	1.537	5.81
Posttest	21	15	6	2.909	11.52
Valid N (listwise)	21				

Table 5. N-gain score test calculation results

	N	Maximum	Minimum	Std. deviation	Mean
N-gain	21	.89	.00	.27218	.5716
Valid N (listwise)	21				

Table 6 presents the results of the analysis Wilcoxon test. In this, negative ranks or the difference (negative) between MR outcomes for the pretest and posttest is 0 in the N value, mean rank, and sum of ranks. These 0 values indicate no decrease (reduction) from the pretest value to the posttest value, positive ranks, or the difference (positive) between the pretest and posttest mathematics learning outcomes. There are 20 positive data (N), meaning all 20 students experienced increased MR outcomes from pretest to posttest scores. The mean rank or mean increase is 10.50, while the sum of ranks or positive ranks is 210.00. Ties are similar in pretest and posttest scores. Here, the tie value is 1, so it can be said that the same value between the pretest and posttest is 1. Based on the test statistics output, the asymp's known significance (2-tailed) is 0.000 because of the value of 0.000<0.05. It can be concluded that the hypothesis is accepted. This means there is a difference between MR outcomes for pretest and posttest. In addition, PBL has a significant effect on students' MR.

Table 6. Wilcoxon test results

Post test - Pre test	Negative ranks	Positive ranks	Ties	Total	
	0[a]	20[b]	1[c]	21	a. Post test<Pre test
	.00	10.50			b. Post test>Pre test
	.00	210.00			c. Post test=Pre test
Z					
Post test – Pre test	-3.932[b]				a. Wilcoxon signed ranks test
Asymp. Sig. (2-tailed)	.000				b. Based on negative ranks.

3.2. Qualitative findings

3.2.1. Mathematical reasoning analysis results of a masculine subject category (MS)

Figure 1 shows the result of the written work of subjects categorized as masculine (MS) obtained from the MR test. In addition, based on the interview results, every MR activity can be interpreted as finding a relationship pattern, proposing a conjecture, verifying the statement's truth, and generalizing the statement. In finding a relationship pattern, MS did the relationship pattern activity by identifying the length of the square to 1, 2, 3, and 4. Knowing the relationship pattern and finding the correct information is essential to writing what is known and asked in the problem. From the interview, MS mentioned that the length of the side of the square is 32, "*I know the size of the square to 5 is 32 because the size of the square is twice as big as the size of the previous one*." In proposing a conjecture, MS proposed a correct conjecture by calculating the remaining land to plant corn through the rectangular area formula. MS said the remaining land planted with corn was 30 m². "The area of land planted with corn can be calculated using the rectangular area formula. The total land area minus the land area planted with spinach and kale, so 80 m²-50 m²=30 m²."

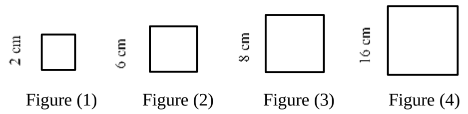
Question: Based on the image below, determine the size of the square and its perimeter in Figure (5)!  Answer: Known: Figure 1 square size 2 cm Figure 2 square size 4 cm Figure 3 square size 8 cm Figure 4 square size 16 cm Asked: What is the size of square 5 is 32 cm Answer: The square size of Figure 5 is 32 cm 16 x 2 Perimeter = 4 x side = 4 x 32 = 128 32 cm	Question: Is there any remaining land for planting corn? (yes/no) Answer: Known: Land size 10 m x 8 m 20 m² of land is planted with spinach 30 m² of land is planted with kale Asked: Is there any land left to plant corn? Answer: Area of land = length x width = 10 x 8 = 80 m² So, the area of land planted with corn is = 80 - (20 + 30) = 80 - 50 = 30 m²
Question: Based on the dialog, try to prove whether Mr. Anton's statement is true? It costs Rp. 48,000 to buy the fabric. Write your answer in this column! Answer: Known: The size of the fabric is 2m x 2m Asked: Is Mr. Anton's statement true? Yes true Answer: The area of the fabric is square = side = 2 x 2 = 4 m² If the price of fabric per m² is Rp. 12,000 Then the money that Mr. Anton must pay is 12,000 x 4 = Rp. 48,000 It is concluded that Mr. Anton's statement	Question: What is the height of the right triangle? Explain how you found the height of the right triangle! Answer: Known: Area of the right triangle = 84 m² The base of the right triangle = 7 m Asked: What is the height of the right triangle? 269 Answer: Area of the right triangle $= \frac{1}{2}$ x base x height $84 = \frac{1}{2}$ x 7 x height 84 x 2 = 168 x height 168 = 84 x 2 x height height = $\frac{168}{269}$ = 269 m (Error 1) MS can generalize statements correctly, but cannot operate division correctly.

Figure 1. Mathematical reasoning test results of masculine subject category (MS)

Masculine verified the truth of Mr. Anton's statement. From the interview, MS said Mr. Anton had to pay Rp. 48,000 to buy the fabric. "The area of the fabric purchased by Mr. Anton is 2 m×2 m=4 m² because the price of fabric per m² is Rp. 12,000, then Rp. 12,000×4=Rp. 48,000." In generalizing the statement, MS generalized the statement when calculating the height value of a right triangle. However, from the results of the MS interview, there was an error in calculating the height value through the right triangle area formula. "The height value can be known using the area formula of a right triangle. The formula for the area of a right triangle is $\frac{1}{2}$ x base x height. The area and base values are already known, namely 84 m² and 7 m. Then, the height of the right triangle is 269 cm." MS generalizes mathematical statements correctly but cannot operate division correctly in calculating the height value through the right triangle area formula, resulting in errors in the problem-solving steps.

3.2.2. Mathematical reasoning analysis results of a feminine subject category (FS)

Figure 2 shows the result of the written work of subjects categorized as feminine (FS) obtained from the MR test. In addition, based on the interview results, every MR activity can be interpreted as finding a relationship pattern, proposing a conjecture, verifying the statement's truth, and generalizing the statement. In finding a relationship pattern, FS did a relationship pattern activity by identifying the length of the square to 1, 2, 3, and 4. From the interview, FS knows the square size is 16×2=32 cm. "The more to the right, the square size increases twice as big. The square size is 2 cm, 2×2=4 cm, 4×2=8 cm, 8×2=16 cm, and 16×2=32 cm." In proposing a conjecture, FS proposed a correct conjecture by calculating the remaining land to plant corn through the rectangular area formula. This can be seen from the ability of the process to understand the problem well because it can find and write down complete important information from the problems presented. FS said the remaining land was planted with corn, 80 m²-50 m²=30 m². "Mrs. Yanti has a land size of 10 m×8 m=80 m². The total land planted with spinach and kale is 50 m², so the remaining land planted with corn is 80 m²-50 m²=30 m²."

In verifying the truth of the statement, FS was wrong because there was an error in calculating the area of the cloth purchased by Mr. Anton. FS believes the answer is correct but is less careful when checking a problem-solving solution. FS should contain the answers that have been done to avoid an error. From the interview, FS said Mr. Anton had to pay Rp. 48,000 to buy fabric, with the price per m² being Rp. 12,000. "The area of the fabric that Mr. Anton bought was 12×4=48 cm², so he had to pay Rp. 48,000 with the price per m² being Rp. 12,000." In generalizing the statement activity, FS generalizes the statement when calculating the height value of a right triangle. However, from the interview, there was an error in calculating the height value through the formula for the area of a right triangle. "The formula for the area of a right triangle is $\frac{1}{2}$ x base x height. So, the height value is 168=269 m".

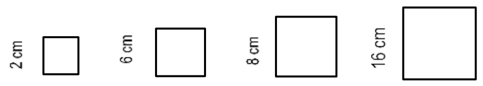
Question: Based on the image below, determine the size of the square and its perimeter in Figure (5)!  Figure (1) Figure (2) Figure (3) Figure (4) Answer: Known: Figure 1 square size 2 cm Figure 2 square size 4 cm Figure 3 square size 8 cm Figure 4 square size 16 cm Asked: What is the size of square 5? Answer: The square size of Figure 5 is 32 cm Perimeter of square = 4 x side = 4 x 32 = 128 cm	Question: Is there any remaining land for planting corn? (yes/no) Answer: Known: Land size 10 x 8 m Planted 20 m² of spinach Planted 30 m² of kale Asked: Is there any land left to plant corn? Answer: Yes Area of land = length x width = 10 x 8 = 80 m² So, the area of land planted with corn is = 80 - (20 + 30) = 80 - 50 = 30 m²
Question: Based on the dialog, try to prove whether Mr. Anton's statement is true. It costs Rp. 48,000 to buy the fabric. Write your answer in this column! Answer: Known: The size of the fabric is 2m x 2m Asked: Is Mr. Anton's statement true? Answer: True The area of the fabric is square = side x side = 12 x 2 = 48 m² If the price of fabric per m² is Rp.12,000 Then the money that Mr. Anton must pay is 12,000 x 4 = Rp. 48,000 It is concluded that Mr. Anton's statement is true (Error 1) FS can verify the truth of the statement, but there is an error calculating the area of the fabric.	Question: What is the height of the right triangle? Explain how you found the height of the right triangle! Answer: Known: Area of the right triangle = 84 m² The base of the right triangle = 7 m Asked: What is the height of the right triangle? Answer: Area of the right triangle = $\frac{1}{2}$ x base x height 84 = $\frac{1}{2}$ x 7 x height 84 x 2 = 168 x height 168 = 84 x 2 height (Error 2) FS can generalize statements correctly, but cannot operate division correctly.

Figure 2. Mathematical reasoning test results of feminine subject category (FS)

3.2.3. Mathematical reasoning analysis results of a neutral subject category (NS)

Figure 3 shows the result of the written work of subjects categorized as neutral (NS) obtained from the MR test. In addition, based on the interview results, every MR activity can be interpreted as finding a relationship pattern, proposing a conjecture, verifying the statement's truth, and generalizing the statement. In finding a relationship pattern, NS did the relationship pattern activity by identifying the size of the squares to 1, 2, 3, and 4. From the interview, NS knew the length of the side of the square was 2×16=32 cm but was wrong in calculating the concept of perimeter. "The length of the side of the square is twice as big as the previous picture, so 2×16=32 cm." In proposing a conjecture, NS proposed a correct conjecture by calculating the remaining land to plant corn through the rectangular area formula. NS mentioned that the remaining land to plant corn is 30 m². "The remaining land for planting corn means the area of Mrs. Yanti's land minus the amount of land planted with spinach and kale, so 80-(20+30)=30 m²."

Neutral subject category verified the truth of Mr. Anton's statement. From the interview, NS mentioned that Mr. Anton had to pay Rp. 48,000 to buy 4 m² of fabric. "The fabric size is 2 m×2 m=4 m² and the price per m² is Rp. 12,000. So, Mr. Anton has to pay 4×Rp. 12,000=Rp. 48,000." In generalizing the statement, NS generalized the mathematical statement correctly but did not correctly operate the division in calculating the height value of the right triangle. From the interview results, NS generalized the mathematical statement through the formula for the area of a right triangle. "The height value can be known through the formula for the area of a right triangle, which is $\frac{1}{2}$ x base x height. The area of a right triangle is 84 m², and the base is 7 m. So, the height value is $\frac{168}{7}$ =... m."

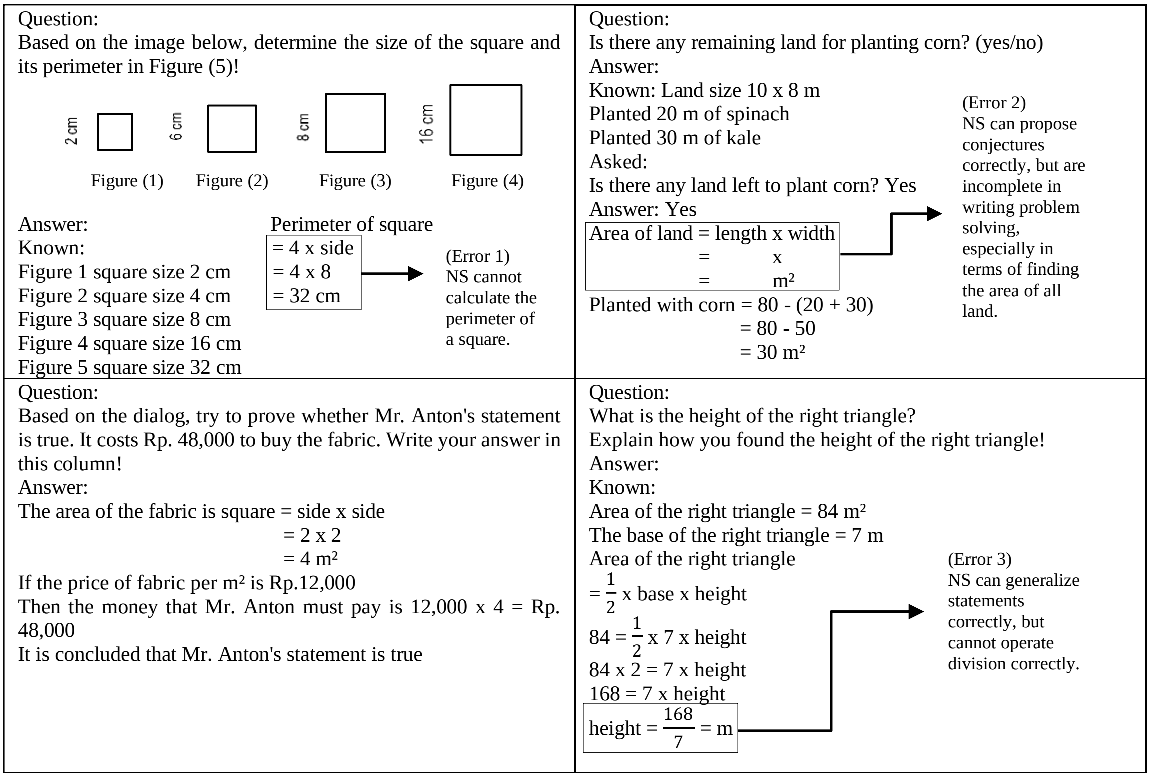


Figure 3. Mathematical reasoning test results of neutral subject category (NS)

Based on the analysis of the research results, several findings can be listed and elaborated quantitatively and qualitatively. Quantitative findings show that students' MR increased in the medium category after implementing PBL. In this, the implementation of PBL significantly affects students' MR. These findings are consistent with previous findings regarding MR problem-oriented learning interventions in experimental research designs [4], [10]–[15], [34]–[36]. Experts explain that PBL has characteristics of problem-solving steps, leading to higher-level thinking development [14], [15]. MR for problem-solving is facilitated through active interaction using thinking skills, including MR during learning [6].

Qualitative findings show that students who have different gender perspectives in terms of masculine, feminine, and neutral have different MR. This finding can be seen as consistent with previous studies that gender differences are a factor or can result in differences in MR [16], [19], [27], [37]–[43]. In this, there were no students with androgynous gender identity in primary school. This phenomenon is caused by children who are at the elementary school level and tend not to have stable gender stereotypes [44], [45], so it is scarce for children to have androgynous, which represents gender with equally strong masculine and feminine traits [46].

Masculine subject category identified can find a relationship pattern, propose a conjecture, and correctly verify the statement's truth but are wrong in generalizing the statements. FS is identified as known to find a relationship pattern and propose a conjecture but is wrong in verifying and generalizing the statements. Meanwhile, NS identified cannot find a relationship pattern, proposing a conjecture and generalizing the statements, but are correct in verifying the truth of the statements. No qualitative study results are precisely the same as these findings, where student MR is elaborated based on the perspective of gender differences after PBL implementation. However, some parts of the findings can be said to be consistent and can be further elaborated with related studies. MS and FS successfully found a relationship pattern and proposed a conjecture, while NS failed. Students who succeeded in finding a relationship pattern and propose a conjecture because students succeeded in identifying important or unimportant information based on problem questions, then connecting it with possible strategies and problem-solving [37], [38], [47]. Only FS is wrong in verifying the statement. Students believe the answer is correct but are careless in rechecking the solution [48]. All subjects (MS, FS, and NS) failed to generalize the statements. These findings are consistent with several studies [3], [16], [49]–[52]. The activity of generalizing the statements is the most difficult to do because it requires abstraction skills [53]–[55] and relational understanding [25], [56]–[58]. It is also caused by students failing to represent problems in mathematical models [49].

The findings of this study provide comprehensive new empirical evidence that the MR of students with different gender perspectives can be improved or influenced significantly through the implementation of PBL. What comprehensiveness means is that the study's results provide quantitative empirical evidence that students' MR can be increased through PBL. It provides qualitative empirical evidence that MR students with different gender perspectives have their own success or failure in each MR activity after implementing PBL. Based on these findings, practical, theoretical, or methodological contributions or implications can be synthesized. Regarding practical educational or empirical contributions, the findings are helpful for teachers or practitioners in that the teaching materials that are prepared, especially into PBL learning steps by also paying attention to gender, have been proven to improve MR students who have problems. In this case, PBL can be a consideration for policymakers to select and maintain as the best learning model to encourage students' academic achievement levels [59]–[62] and avoid gender bias in education [28], [46], [63]–[65]. Therefore, the findings can also be used for policymakers to maintain PBL as a learning model to achieve standard mathematics competencies by avoiding gender bias. Regarding theoretical contribution, the study findings strengthen the results of previous research that PBL can significantly improve MR, as well as initial findings that MR with a gender perspective can be influenced through PBL. Finally, the study findings provide a methodological contribution in terms of the availability of research results that not only assess MR quantitatively after implementing PBL, but assess MR in depth and descriptively from a gender perspective.

4. CONCLUSION

The study results can be concluded quantitatively and qualitatively. Quantitatively, it can be concluded that implementing problem-based learning significantly affects students' mathematical reasoning from different gender perspectives. In this, there is an increase in mathematical reasoning before and after applying problem-based learning. Meanwhile, it is qualitatively concluded that students with different gender perspectives in terms of masculine, feminine, and neutral have different mathematical reasoning after applying problem-based learning. Students with masculine gender identity can find a relationship pattern, propose a conjecture, and correctly verify the statement's truth but are wrong in generalizing the statements. Students with feminine gender identity can know to find a relationship pattern and propose a conjecture but are wrong in verifying and generalizing the statements. Students with neutral gender identity cannot find a relationship pattern, proposing a conjecture and generalizing the statements, but are correct in verifying the truth of the statements. On the other hand, although the study's results show positive things, the study was carried out with a relatively small sample of participants. Apart from that, the study results show that there are students' mathematical reasoning activities in generalizing the statement that is still problematic or inadequate. Thus, we recommend that the next study conduct further research on assessing students' mathematical reasoning by still considering differences in gender perspective but through problem-based learning interventions involving a broader research sample, as well as strengthening generalizing the statement activities that are more meaningful and constructive.

ACKNOWLEDGEMENTS

The authors want to thank the Universitas Muhammadiyah Sidoarjo as the funder of research and publications, as well as all parties involved in the study, so that the pedagogical practice of this research can be carried out.

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