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Enhancing critical thinking with realistic mathematics education: Insight from learning styles, thinking habits, and cognitive abilities

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Abstract

Although critical thinking is vital in 21st-century learning, mathematics classes often emphasise procedures over reasoning. Few studies have explored how students' characteristics (learning styles, thinking habits, and cognitive abilities) interact with contextual learning approaches such as *Pendidikan Matematika Realistik Indonesia* (PMRI). This study aimed to describe the students' critical thinking using PMRI as a learning approach, specifically by analysing how these abilities vary based on students' learning styles, thinking habits, and cognitive ability levels. The context of water pH was used to explore the measures of central tendency. Students were observed based on their learning styles, thinking habits, and cognitive abilities. This study used a descriptive qualitative method with 29 eighth-grade students from junior high school in Palembang. Data were collected through tests, questionnaires (learning styles and thinking habits), and the participants' academic records. The data were analysed using Miles, Huberman, and Saldana's model, which involves data reduction, presentation, and conclusions. The results show that female students tend to possess "quite critical category", while male students also show "quite critical category" category when analysed by learning style, but lower in thinking habits and cognitive ability. This implies that teaching should consider students' differences to support the development of critical thinking.

Keywords: cognitive ability; critical thinking ability; learning style; thinking habits

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Introduction

Critical thinking is one of the essential skills in the 21st century (Almulla, 2018; As'ari et al., 2019; Spector & Ma, 2019; Yılmaz-özcan & Tabak, 2019; Zetriuslista et al., 2016). Critical thinking skills involve the process of thinking more deeply rather than immediately accepting information and remaining open to different perspectives or views (Karakoç, 2016). When faced with mathematical problems, students need to make reasonable and reflective decisions to obtain the correct solutions (Apiati & Hermanto, 2020; Chukwuyenum, 2013; Prasetyawan, 2018). Learning to think critically involves learning how to ask questions, when to ask them, what the questions are, how to reason, when to use reasoning, and which reasoning methods to employ (Palinussa, 2013). People who possess critical thinking skills can make better decisions (Munawwarah et al., 2020). Most students can solve mathematical problems more easily once they fully understand the underlying concepts. When students develop a solid understanding of mathematics, they can make meaningful connections between ideas, which enables them to identify and apply appropriate strategies to solve problems effectively. Therefore, students need to be trained in high-level thinking skills, one of which is the ability to think critically (Hanifatulianti & Sumitro, 2023).

However, in practice, many students struggle to apply mathematical concepts meaningfully, particularly when dealing with real data. One common difficulty in understanding statistical concepts is that students often rely on memorising formulas rather than interpreting data. This study focuses on measures of central tendency, which include the mean, median, and mode (Siregar, 2015). The concepts in the material on data centralisation measures must be known by students, including 1) the average, which is a measure of central tendency calculated by dividing the total sum of all data values by the number of values (Franklin & Mewborn, 2007); 2) the concept of the median, which is dividing a series of data into two equal parts, namely, 50% of the total data value is above the median value and the other 50% value is below the median value (Cazorla et al., 2023); and 3) the mode which is a series of data with the most frequently occurring value or the condition with the most frequency (Cazorla et al., 2023).

Rahayu (2021) showed that the learning process for this topic was carried out by directly providing formulas without first studying the basic concept of the average. This causes students to struggle with solving new problems that are not similar to the examples given. In addition, another study showed that 80% of students made mistakes in determining the average value and 83% of them made errors in analysing data (Dewi et al., 2020). Moreover, the results of previous studies also stated that students had difficulty determining the median, quartiles, and average. A common mistake when determining the median is not sorting the data from smallest to largest; instead, students directly determine the middle value of the data presented (Yusuf et al., 2017).

Several factors contribute to students' difficulty in solving mathematical problems, which, in turn, results in low critical thinking skills. These are conventional approaches to learning (Rahayu & Putri, 2021; Sari & Nursyahidah, 2022) and do not relate problems to real-life situations (Nasrulloh & Amin, 2022). Therefore, innovation is required to improve students'

critical thinking skills using the right strategy or approach. The Pendidikan Matematika Realistik Indonesia (PMRI) approach is one strategy that is particularly suitable for solving this problem (Hikayat et al., 2020; Nasrulloh & Amin, 2022; Palinussa, 2013). Several studies have found that critical thinking skills using the PMRI approach are superior to those acquired through conventional learning (Hikayat et al., 2020; Lambertus et al., 2016; Palinussa, 2013). Additionally, the PMRI approach enhances conceptual understanding during the learning process (Nova et al., 2022).

Furthermore, critical thinking skills can be influenced by learning styles (Apiati & Hermanto, 2020; Utami et al., 2020). Previous studies have shown that students' learning styles can significantly impact the effectiveness of their learning, making it essential for teachers to understand these styles to develop appropriate instructional methods (Putri et al., 2024). Learning style is a person's characteristic for obtaining information to facilitate the learning process (Subini, 2015). In other words, each student has a unique learning style, and some have a combination of visual, audio, and kinesthetic learning styles (Purwanto et al., 2020). Other factors that affect critical thinking skills include thinking category (right brain, left brain) and cognitive abilities (high, medium, and low), which can also influence the process (S. N. Sari & Rosyidi, 2025).

Previous studies have shown that the PMRI approach is effective in enhancing students' conceptual understanding and critical thinking skills (Hikayat et al., 2020; Palinussa, 2013). However, most of these studies focus primarily on the instructional approach itself, without considering individual student characteristics in depth, such as learning styles, thinking habits, and cognitive abilities. However, studies that address individual factors often examine them in isolation and have yet to integrate them within the context of PMRI-based learning (Apiati & Hermanto, 2020; Munawwarah et al., 2020).

The novelty of this study lies in the combination of the PMRI approach based on real-world contexts with a detailed analysis of three student characteristics: learning styles, thinking habits, and cognitive ability levels. These variables were examined together to determine their combined influence on students' critical thinking performance. Using water pH as a contextual theme serves as a meaningful and practical entry point for exploring the topic of measures of central tendency. This study aimed to describe junior high school students' critical thinking abilities in a PMRI-based statistics lesson, with a specific focus on how these abilities vary based on students' learning preferences, thinking habits, and levels of cognitive ability.

Methods

This study employed a qualitative descriptive method. According to Borg and Taylor, qualitative research is a research procedure that produces descriptive data in the form of written or spoken words from people and observable behaviours (Kodu et al., 2019). The aim was to qualitatively describe students' critical thinking skills based on the qualitative data obtained. The study was conducted at a junior high school in Palembang because the school represented a diverse student population in terms of learning styles, thinking habits, and cognitive abilities, making it a suitable setting for this research. The participants were 29 eighth-grade students.

The instruments used in this study included tests, questionnaires, and documents. The researchers developed a critical thinking test based on Facione's (2013) framework, which covers four indicators: interpretation, analysis, evaluation, and inference, as presented in Table 1.

Table 1. Indicators of critical thinking skills based on facione

Indicator	Description
Interpretation	Students can identify the problem by writing what is known and what is being asked for correctly and completely.
Analysis	Students can recognize the relationship between the question and the mathematical concepts involved by constructing appropriate models and explanations.
Evaluation	Students can choose the right strategy, and solve the problem accurately and completely, including precise calculations.
Inference	Students can draw accurate and complete conclusions based on the context of the question.

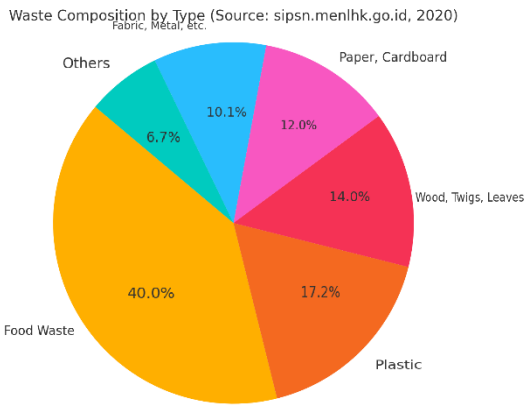
These indicators reflect the cognitive processes involved when students engage with mathematical problems. Based on these indicators, the criteria for students' critical thinking skills are as follows Table 2.

Table 2. Criteria for students' critical thinking skills

Average Score	Criteria
$80 < p \leq 100$	Very Critical
$75 < p \leq 79$	Critical
$40 < p \leq 74$	Quite Critical
$20 < p \leq 39$	Less Critical
$0 < p \leq 19$	Not Critical

The items were validated by two experts in statistics and one in mathematics education and were revised based on their feedback to ensure content validity. A trial test was conducted with a group of students outside the research sample to check for clarity and reliability. Learning style questionnaires are used to measure whether students are included in the audio, visual, or kinesthetic learning styles. Thinking habits questionnaires were given to students to categorise their thinking habits and determine whether they tended to use the left or right brain in learning. Learning style and thinking habit questionnaires were adapted from previous studies and adjusted to the junior high school level. Documentation was conducted to assess students' cognitive abilities and categorise them into high, medium, or low categories, respectively. In this process, teacher assessments served as the primary source of data, encompassing classroom participation and the completion of tasks. The critical thinking ability test was given in the form of three descriptive questions as follows:

1. The diagram on the side shows that the waste obtained in 2020 reached 68 million tons. This means that there are around 185 tons produced daily by 270 million people in Indonesia.



   a. What information can you get from the problem above?
   b. How much plastic waste was produced in 2020?
   c. How much organic waste is produced?
   d. What is the difference between organic waste and plastic waste?
   e. What can you conclude regarding the composition of waste in the diagram above?
2. The following are the results of measurements from various water sources, the pH data obtained are as follows:

No	Water Sources	Water Ph
1	Well water 1	4
2	Well water 2	6
3	Zam-zam water	7
4	Lime juice	3
5	Lemon juice	2
6	PDAM water	7
7	Air conditioning water	4
8	Gallon of water 1	5
9	Gallon of water 2	?

   What is the pH of 2 gallons of water, if the average pH of water is known = median = 5? What can you conclude?
3. Mr. Doni is a drinking water supplier in the Prima housing complex. To maintain water quality and calculate the cost of purchasing water sources, Mr. Doni conducted a trial using three water sources in the Prima housing complex: PDAM, wells, and rivers. After testing, the average water pH data was obtained at 5. Seeing that the water pH is below the standard limit, what should Mr. Doni do to bring the water pH back to normal?

The data analysis technique employed in this study utilises a model developed by Miles, Huberman, and Saldana, which involves three stages: data reduction, data presentation, and conclusion data analysis technique in this study uses a model developed by Miles, Huberman, and Saldana, namely through three stages, namely data reduction, data presentation, and drawing conclusions (Sugiyono, 2015). 1) The data reduction stage is carried out by correcting the results of the questionnaire that has been completed to see the characteristics of students based on gender in terms of learning styles and thinking habits, while to see their cognitive abilities are obtained from the results of students' daily tests, then the results are arranged to determine students' critical thinking habits; 2) data presentation is done by presenting test result data according to student characteristics in the form of a bar chart; 3) concluding is done by comparing the results of student work based on gender which is reviewed from learning styles,

thinking habits, and cognitive abilities, so that conclusions can be drawn on how students think critically.

Results

Data reduction

At this stage, data on student characteristics were collected through questionnaires and documentation in the form of daily score tests. The data covered three main aspects: learning styles (visual, auditory, and kinesthetic), thinking habits (left- and right-brain dominance), and cognitive abilities (high, medium, and low). These characteristics were then grouped and analysed by gender to examine their relationship with critical thinking performance. The data are presented in Table 2 as follows:

Table 2. Student characteristic data results

Gender	Learning Styles			Thinking Habits		Cognitive Abilities			Total
	Visual	Audio	Kinesthetic	Left Brain	Right Brain	High	Medium	Low	
Male	9	3	4	12	4	6	3	7	16
Female	9	3	1	9	4	3	7	3	13
Total	18	6	5	21	8	9	10	10	29

As shown in Table 2, male and female students predominantly have a visual learning style, accounting for 62% (18 of 29 students). This indicates that students prefer learning that uses visual representation. Furthermore, for thinking habits, male students use the left brain more (12 people compared to females, 9 people) and the rest use the right brain, for cognitive abilities, males also have higher abilities (6 people) than females (3 people).

After obtaining data on student characteristics, the next stage was to create learning tools using the PMRI approach, with a focus on the context of water pH. There are three principles of using the PMRI approach: 1) Guided Reinvention and Didactic Phenomenology, where students are allowed to build and rediscover mathematical ideas and concepts; 2) Progressive mathematisation, which emphasises the process of solving a problem based on two mathematisationstizations, namely vertical and horizontal; and 3) self-developed model, which shows the existence of a bridge function to deliver students to formal mathematics. Not only that, PMRI also has characteristics, some opinions say there are 5 characteristics of PMRI some others say there are 6 characteristics as follows: 1) Reality, which provides opportunities for students to explore informal knowledge through contextual situations, namely by introducing students to water pH, 2) Level, which is a learning process that moves from concrete to abstract, starting from the context of water pH to mathematical formulas (mean, median, mode), 3) Activity, which is a characteristic that emphasizes student activities through Student Activity Sheets, 4) Guidance, which provides students with the opportunity to learn with the guidance of educators, 5) Interactivity, which is a characteristic based on the idea of the importance of discussion, communication and collaboration, 6) Intertwinement, which is the connection between mathematics and activities carried out, namely by connecting science subject matter through measuring water pH to provide a broader understanding of the application of

mathematics to students. Through these six characteristics, a visualisation in the form of an iceberg is depicted for learning using the PMRI approach, as presented in Figure 1 below:

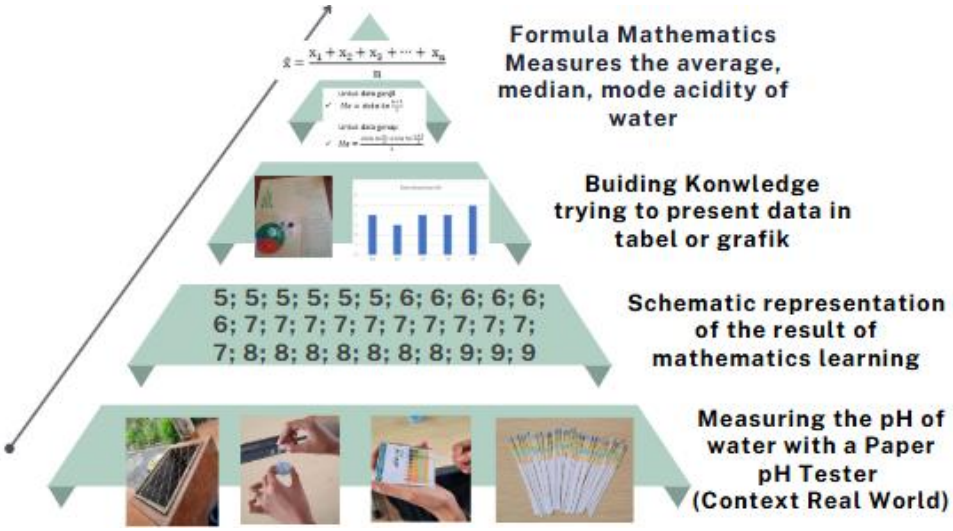


Figure 1. Iceberg in the PMRI approach

Figure 1 illustrates an iceberg that represents the learning process, starting from a real-world situation, where the pH of water is measured. Students are allowed to represent data from the pH of water using a mathematical scheme, then build their knowledge from the data obtained, presented in the form of a table or graph. Ultimately, students can understand the concepts of average, median, and mode in the context of mathematical formulas.

Data presentation

Based on the results of the reduction that has been carried out, the next stage is to present the test result data according to student characteristics in the form of a bar chart for 29 students based on gender in terms of learning styles, thinking habits, and cognitive abilities of students obtained as follows:

1. **Student learning styles**

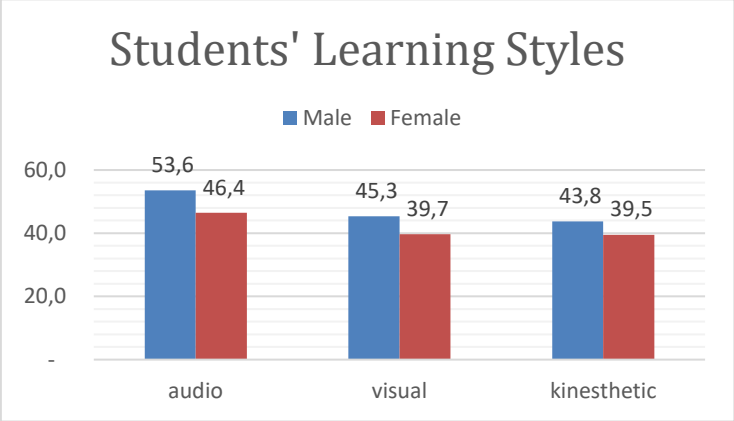
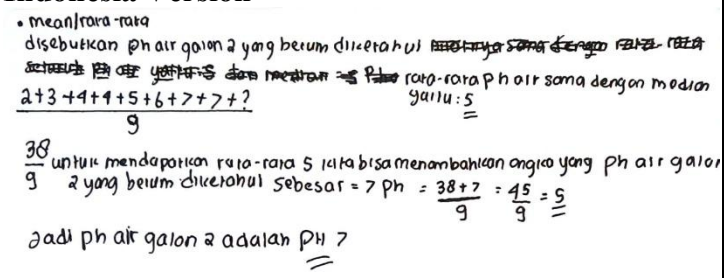


Figure 2. Diagram of average value of students' critical thinking ability reviewed from learning style

Based on Figure 2, the average values for the students were obtained according to their learning styles. Male students with an audio learning style had an average value of 53.6, which falls into a quite critical category. In contrast, female students had an average value of 46.4, which also fell into a critical category. When comparing male and female students in terms of audio learning style, male students had higher average values than female students. Furthermore, male students with a visual learning style obtained an average value of 45.3, which is quite critical, while female students obtained an average value of 39.7, which is also quite critical. Similarly, when comparing the audio learning style between male and female students in terms of the visual learning style, male students had higher average values than female students. Male students with a kinesthetic learning style obtained an average value of 43.8, which falls into a quite critical category.

In contrast, female students obtained an average value of 39.5, which also fell into a critical category. When comparing male and female students in terms of the kinesthetic learning style, males tended to have higher average scores than females. The results of students' answers with audio, visual, and kinesthetic learning styles were as follows:

Indonesia Version



English Version

Mean

It is stated that the pH of gallon 2 of water is unknown, and

The average pH of water is the same as the median, which is 5.

$$\frac{\mathbf{2+3+4+4+5+6+7+7+?}}{\mathbf{9}}$$

$$\frac{\mathbf{38}}{\mathbf{9}}$$

to get an average of 5 we can add the unknown number of pH of gallon 2 of water, which is 7 pH.

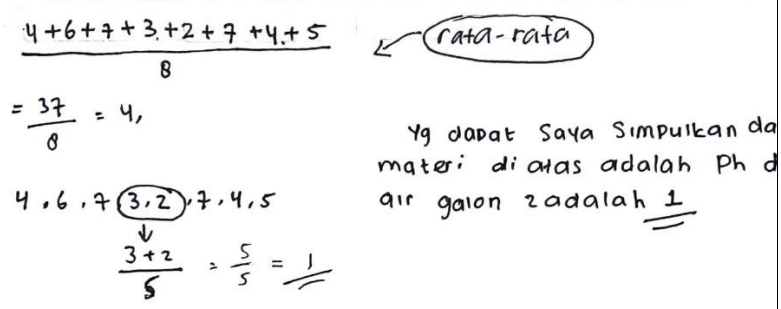
$$\frac{\mathbf{38+7}}{\mathbf{9}} = \frac{\mathbf{45}}{\mathbf{9}} = \mathbf{5}$$

So the pH of gallon 2 of water is pH 7.

Figure 3. Student answer results (RA) with audio learning style

Based on Figure 3, the results of RA students' answers regarding audio learning styles have led to four indicators. In the interpretation indicator, students have written what is known and asked in the question. As seen from their answers, students already know the unknown pH information and understand that the average is the same as the median, which is 5. In the analysis indicator, it is shown that students have connected the questions and concepts given in the question, even without creating a mathematical model; however, their answers have led to the correct solution by creating a mathematical model $\frac{\mathbf{2+3+4+4+5+6+7+7+?}}{\mathbf{9}}$. In the evaluation indicator, the student uses a strategy to solve the problem by adding the pH data of gallon 2 water (7) to get an average pH of 5 so that $\bar{\boldsymbol{x}} = \frac{\mathbf{38+7}}{\mathbf{9}} = \frac{\mathbf{45}}{\mathbf{9}} = \mathbf{5}$. In the inference indicator, students can draw accurate and complete conclusions based on the context of the problem.

Indonesia Version



English Version

Mean:

$$\frac{4+6+7+3+2+7+4+5}{8}$$

$$=\frac{37}{8}=4$$

$$4, 6, 7, 3, 2, 7, 4, 5$$

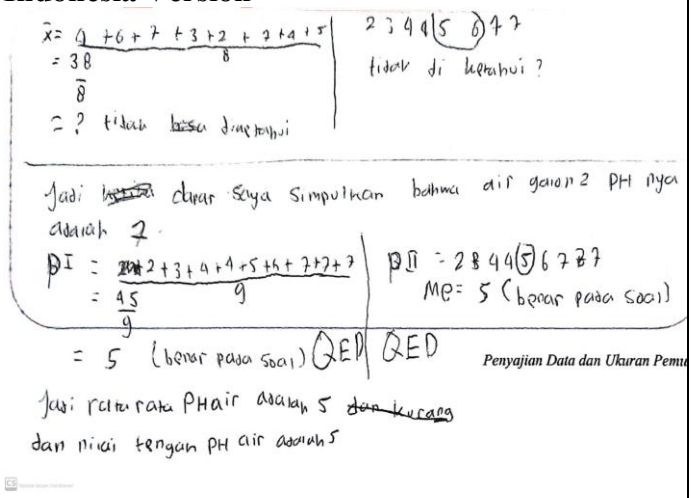
$$\frac{3+2}{5}=\frac{5}{5}=1$$

What I can conclude from the material above is that the pH of gallon 2 water is 1.

Figure 4. Student answer results (R) with visual learning style

Figure 4 shows the results of the student's answers (R) with a visual learning style, which have led to four indicators. In the interpretation indicator, students do not write down what is known and asked in the question; however, it can be seen from their answers that students already know the information in the question. In the analysis indicator, it is shown that students have connected the queries and concepts given in the question, even without creating a mathematical model; however, students' answers have led to the correct answer by making $\frac{4+6+7+3+2+7+4+5}{8}=\frac{37}{8}$. The evaluation indicator student using the wrong strategy in solving problems by adding the middle data and then dividing it by 5. In the inference indicator, students have not been able to draw correct conclusions based on the context of the problem.

Indonesia Version



English Version

$$\bar{x}=\frac{4+6+7+3+2+7+4+5}{8}$$

$$=\frac{38}{8}$$

$$= ?\ \text{is unknown}$$

2 3 4 4 5 6 7 7

Tidak diketahui?

So the pH of 2 gallons of water is 7

$$PI = \frac{2+3+4+4+5+6+7+7+7}{9}$$

$$=\frac{45}{9}$$

$$= 5\ \text{(That's right in the question)}$$

$$PII = 2\ 3\ 4\ 4\ 5\ 6\ 7\ 7\ 7$$

Me= 5 (That's right in the question)

So, the average pH of water is 5 and the median pH of water is 5

Figure 5. Student answer results (RA) with kinesthetic learning style

Based on Figure 5, the results of RA students' answers, which indicate kinesthetic learning styles, have led to four indicators. In the interpretation indicator, students do not write what is known and asked in the question; however, it can be seen from their answers that

students already know the information in the question. In the analysis indicator, it is shown that students have connected the queries and concepts given in the question, even without making a mathematical model, but students' answers have led to the answer by making. $\frac{2+3+4+4+5+6+7+7+7}{9}$. In the evaluation indicator, the student uses a strategy to solve problems by adding data on the pH of gallon 2 water, which is 7, to get an average pH of 5 so that $\bar{x} = \frac{45}{9} = 5$. In the inference indicator, students have been able to draw correct conclusions based on the problem's context, even though the layout of the conclusion is not yet correct after the work is completed.

2. Students' thinking habits

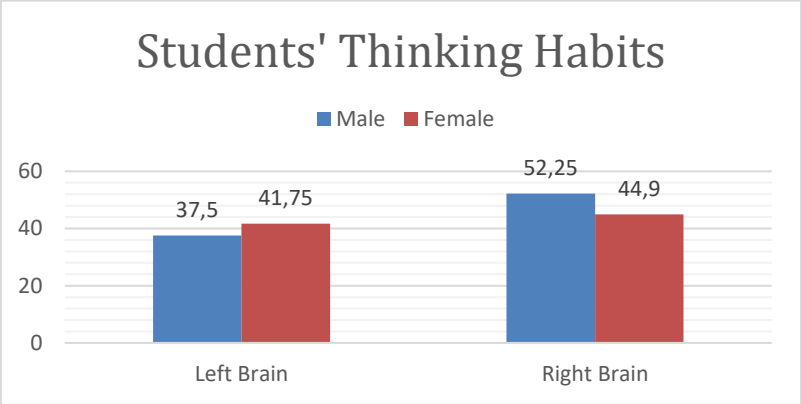
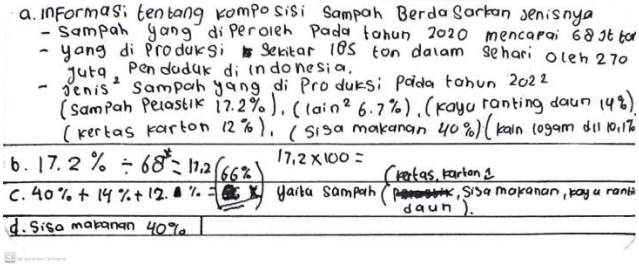


Figure 6. Diagram of average values of students' critical thinking skills viewed from the habits of thinking

Based on Figure 6, the average value is obtained according to the students' thinking habits. Male students who tend to use the left brain receive an average score of 37.5, which falls into a less critical category. In contrast, females receive an average score of 41.75, which falls into a quite critical category. When comparing male and female students in terms of left-brain thinking habits, male students have lower average scores than female students. Furthermore, male students with right-brain thinking habits receive an average score of 52.25, which is quite critical, while females receive an average score of 44.9, also quite critical. When comparing male and female students in terms of right-brain thinking habits, male students have higher average scores than female students. The results of students' answers with left and right brain thinking habits are as follows:

Indonesian Version



English Version

a. Information about waste composition based on its type
   - Waste obtained in 2020 reached 68 million tons, which was produced at a rate of approximately 185 tons per day by 270 million people in Indonesia.
   - Types of waste produced in 2022 (plastic waste 17,2%), (others 6.7%), (wood twigs leaves 14%), (paper cardboard 12%), (food waste 40%), (metal cloth 10.17%).

b. $\mathbf{17.2\% : 68 = 17.2 \times 100}$

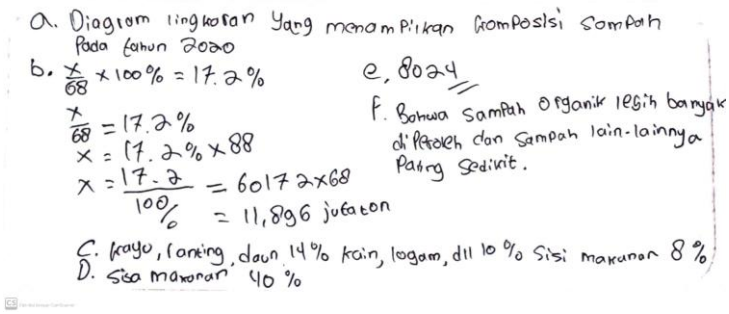
c. $\mathbf{40\% + 14\% + 12\% = 66\%}$ namely waste (cardboard, food waste, wood, twigs, leaves)

d. food waste 40%

Figure 7. Student answer results (DAPS) with left brain thinking habits

Figure 7 shows the results of the DAPS students' answers, indicating a habit of thinking that utilizes the left hemisphere of the brain. In the interpretation indicator, students have written what is known and asked in the question, as evident from their answers to question no. 1a, namely providing information about the waste data obtained in 2020, reaching 68 million tons, waste production of 185 tons per day, and there are types of waste with varying percentages. In the analysis indicator, it is shown that students have not connected the questions and concepts presented in the question, as evidenced by answers that do not understand how to obtain data, which is only provided as average and percentage results. In the student evaluation indicator, the student has not employed effective problem-solving strategies. In the inference indicator, students have not been able to draw correct conclusions based on the context of the problem.

Indonesian version



English version

a. Pie chart showing the composition of waste in 2020.

b. $\frac{x}{68} \times 100\% = 17{,}2\%$
$\frac{x}{68} = 17{,}2\%$
$x = 17{,}2\% \times 88$
$x = \frac{17{,}2}{10\%} = 60172 \times 68 =$ 11,896 million tons

c. wood, twigs, leaves 14% cloth, metal, etc. 10% Food waste 8%

d. leftovers 40%

e. 8024

f. That more organic waste is obtained and the less other waste

Figure 8. Results of student answers (RA) with right brain thinking habits

Based on Figure 8, the results of RA students' answers indicate that the habit of thinking using the right brain has led to four indicators. In the interpretation indicator, students have written down what is known and asked in the question, as evident from their answers to question no. 1a, namely, providing information about a pie chart showing the composition of waste in 2020. In the analysis indicator, it is shown that students have connected the questions and concepts given in question 1b by creating a mathematical model $\frac{\boldsymbol{x}}{\boldsymbol{68\ million\ tons}} = \mathbf{17.2}\ \%$. In the evaluation indicator, students using strategies in solving problems by operating from mathematical models that have been made, only in the process, students are still wrong, so the final result is not correct which should be written $\boldsymbol{x = 17.2\ \% \times 68\ million\ tons}$ but is written $\boldsymbol{x = 17.2\ \% \times 88\ million\ tons}$ and causes the final result to be incorrect. In the

inference indicator, students can draw conclusions based on the context of the question, as seen in answer 1f. Only for solving 1b, 1c, and 1d, students have not made conclusions.

3. Students' cognitive abilities

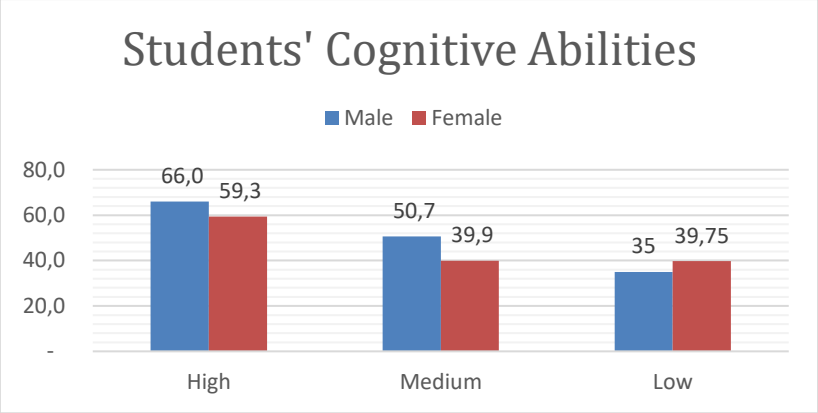
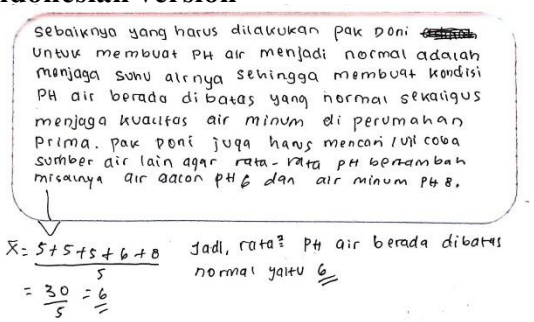


Figure 9. Diagram of average values of students' critical thinking skills reviewed from students' cognitive abilities

Based on Figure 9, the average value of students' critical thinking skills is obtained according to their cognitive abilities. Male students with high abilities receive an average score of 66, which falls into a quite critical category. In contrast, female students receive an average score of 59.3, also falling into a quite critical category. When comparing male and female students in terms of high ability, male students have a higher average score than female students. Furthermore, male students with medium abilities achieve an average score of 50.7, which falls into a quite critical category. In contrast, female students gain an average score of 39.9, also in a quite critical category. When comparing male and female students in terms of median ability, male students have a higher average score than female students. Male students with low skills receive an average score of 35 in a less critical category, while female students achieve an average score of 39.75 in a more critical category. When comparing male and female students in terms of low ability, female students have a higher average score than male students. The results of students' answers, reviewed from cognitive skills, are as follows:

Indonesian version


Sebaiknya yang harus dilakukan pak Doni untuk membuat PH air menjadi normal adalah menjaga suhu airnya sehingga membuat kondisi PH air berada di batas yang normal sekaligus menjaga kualitas air minum di perumahan Prima. Pak Doni juga harus mencari/uji coba sumber air lain agar rata-rata PH bertambah misalnya air galon PH 6 dan air minum PH 8.

$\bar{X} = \frac{5+5+5+6+8}{5}$ jadi, rata2 PH air berada dibatas normal yaitu 6

$= \frac{30}{5} = 6$

English version

To normalize the water pH, Mr. Doni should maintain the water temperature to keep the pH within normal limits while ensuring the quality of drinking water in the Prima housing complex remains optimal. Mr. Doni should also look for and test other water sources to increase the average pH, for example, gallon water with a pH of 6 and drinking water with a pH of 8.

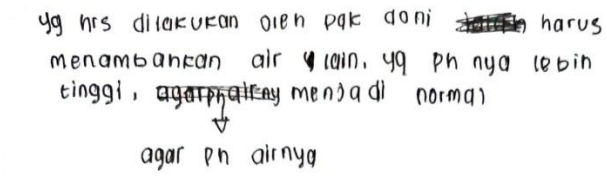
$$\bar{X} = \frac{5+5+5+6+8}{5} = \frac{30}{5} = 6$$

So, the average pH of water is within the normal limit, namely 6.

Figure 10. Results of student answers (AM) with high cognitive abilities

Figure 10 shows that AM students with high cognitive skills can formally interpret, analyze, evaluate, and infer. Based on the results of the answers from students with high cognitive abilities, four indicators have been identified. In the interpretation indicator, students do not write what is known and asked in the question; however, it can be seen from their answers that students already know the information in the question. In the analysis indicator, it is shown that students have connected the queries and concepts given in the question, even without creating a mathematical model; however, students' answers have led to the correct answer by making $\bar{X} = \frac{5+5+5+6+8}{5}$. In the evaluation indicator, using a strategy to solve the problem by adding two water sources with pH of 6 and 8, respectively, but not correctly adding them, and in the inference indicator, students can make conclusions according to the context of the problem. However, the wrong addition process causes the final result to be incorrect.

Indonesian version



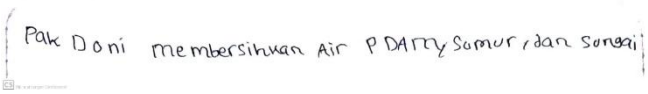
English version

What Mr. Doni has to do is add other water, which has a higher pH, so that the pH of the water becomes normal.

Figure 11. Results of student answers (RA) with medium cognitive ability

Figure 11 shows the results of the answers of RA students with medium cognitive abilities, who have moved towards three indicators. In the interpretation indicator, students do not write what is known and asked in the question; however, it can be seen from their answers that students already know the information in the question. In the analysis indicator, it is shown that students have not connected the queries and concepts given in the question by creating a mathematical model. In the evaluation indicator, the student uses a strategy to solve the problem by adding other water with a higher pH, but it is not formulated into a mathematical model. In the inference indicator, students can draw conclusions based on the context of the problem without knowing the exact pH level of the water that must be added to make the water normal.

Indonesian version



English version

Mr. Doni cleans PDAM water, wells, and rivers

Figure 12. Results of students' answers (MBH) with low cognitive abilities

Figure 12 shows the results of the answers from MBH students with low cognitive abilities, which have led to two indicators. In the interpretation indicator, students do not write down what is known and asked in the question. In the analysis indicator, it is shown that students have not connected the queries and concepts given in the question by creating a mathematical model. In the evaluation indicator, students use strategies to solve problems by cleaning the PDAM water, wells, and rivers. In the inference indicator, students are not yet able to draw conclusions based on the context of the question.

Drawing conclusions

It can be concluded that, based on the results of the analysis, male students demonstrated a higher critical thinking ability than female students, as reviewed from the audio, visual, and kinesthetic learning styles. Furthermore, students' critical thinking abilities, as reviewed from thinking habits, show that male students who tend to use the left brain obtained scores with an average lower than those of female students, while male students who tend to use the right brain obtained scores with an average higher than those of female students. For students' critical thinking ability, as reviewed in cognitive skills, male students with high and medium abilities obtained scores with an average higher than those of female students, while male students with low skills obtained scores with an average lower than those of female students.

However, based on the category of critical thinking skills, it can be concluded that the critical thinking skills of students based on gender as reviewed from learning styles (audio, visual and kinesthetic), thinking habits (right brain and left brain), cognitive abilities (high, medium and low), **female students** have abilities with a "**quite critical**" category. In contrast, **male students** fall into the "**quite critical**" category when viewed from the perspective of learning styles. However, they are categorized as "**less critical**" in terms of their thinking habits and cognitive abilities.

Discussion

The results of this study indicate that students generally possess "quite critical" thinking skills when viewed from the perspectives of learning styles, thinking habits and cognitive abilities. However, there are notable differences between male and female students and among students with different cognitive ability levels. These findings suggest that individual learner characteristics significantly influence performance in the PMRI approach (Nova et al., 2022; Palinussa, 2013).

The bar chart of students' learning styles illustrates that male students consistently outperformed female students across the auditory, visual, and kinesthetic categories. Notably, male students with auditory learning styles achieved the highest average score (53.6) compared to 46.4 for female students. A similar pattern emerged for visual (45.3 vs. 39.7) and kinesthetic (43.8 vs. 39.5) learners, suggesting that male students are more responsive to multimodal instruction. These results are consistent with those of Delina and Afrilianto (2025) and Hariri et al. (2025), who confirmed that kinesthetic and visual-spatial learners benefit more from contextualised mathematics tasks. The implication is clear: to enhance critical thinking outcomes, PMRI-based instruction must integrate visual aids, physical engagement, and verbal explanations, thus aligning pedagogy with learner preferences.

In terms of thinking habits, the data show that male students achieved the highest average critical thinking score (52.25), while female students scored 44.9. In contrast, female left-brain students (41.75) outperformed their male counterparts (37.5). These findings suggest that students with intuitive and holistic thinking styles perform better in critical thinking tasks.

Right-brain-dominant students, who tend to be more holistic, creative, and intuitive, generally outperform their left-brain peers, especially among male students.

Furthermore, the analysis of students' cognitive ability levels revealed a strong correlation between cognitive capacity and critical thinking. High-ability students scored the highest (66.0 for males, 59.3 for females), followed by medium-ability (50.7 vs. 39.9), and low-ability students (35.0 vs. 39.75). To support learners across all cognitive levels, educators should implement scaffolding strategies and formative feedback in PMRI-based lessons. Tiered assignments, reflective prompts, and adaptive tools can empower all students, particularly those with lower abilities, to develop critical thinking skills incrementally.

These results align with previous research findings, indicating that both learning styles and cognitive abilities significantly influence the ways in which students comprehend mathematical concepts and formulate problem-solving strategies (Putri et al., 2024). Although many studies have explored the influence of learning styles and cognitive abilities on learning outcomes, few have examined the combined effects of learning styles, thinking habits, and cognitive abilities within the context of PMRI-based learning. This reveals a gap in the current literature that this study attempts to fill. Therefore, this study contributes new insights into how individual characteristics affect students' critical thinking in contextual mathematics instruction.

One important finding of this study is the difference in problem-solving strategies between students with left-brain and right-brain thinking patterns. This information can help teachers adapt their instructional approaches to align with students' preferences. This study presents a novel approach by combining the PMRI model with a real-world context (pH of water), while also considering students' diverse cognitive and behavioural characteristics. This combination is relatively rare in the existing literature and contributes to instructional models that address both content mastery and student diversity. The findings also suggest that using local, contextualised content enhances the effectiveness of critical thinking instruction (Revina & Leung, 2019; Zulkardi & Putri, 2010). This study demonstrates that PMRI-based contextual mathematics instruction can foster critical thinking when adapted to students' individual characteristics. Further research is recommended to explore the deeper interactions between learner characteristics and contextual teaching strategies.

Conclusion

The critical thinking skills of students based on gender were reviewed based on learning styles (audio, visual, and kinesthetic), thinking habits (right brain and left brain), and cognitive abilities (high, medium, and low). Female students had abilities in the quite critical category, while male students had abilities in the quite critical category from the perspective of learning styles. When viewed from the perspective of the thinking and cognitive abilities of male students, they had abilities in the less critical category. These variations highlight the influence of learner characteristics on critical thinking performance, particularly in PMRI-based mathematics learning.

Given that this study represents an initial exploration, future research should involve larger and more diverse student groups to evaluate and refine the effectiveness of the learning design more accurately. Larger-scale investigations are essential to validate the findings of this study and support their wider applicability. Moreover, the positive outcomes observed from integrating local contexts, such as water pH, in PMRI-based mathematics learning highlight the importance of embedding contextual and relevant materials into instructional practices. This approach not only enhances student engagement and motivation but also deepens conceptual understanding by providing meaningful and authentic learning experiences to students. Therefore, this study offers a strong foundation for curriculum developers to explore and implement innovative, student-centred, and evidence-based instructional strategies in the future. These strategies also promote inclusive education by addressing diverse learner characteristics and aligning with the demands of 21st-century learning.

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Conflicts of Interest

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

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Author Contributions

Allen Marga Retta: Conceptualization, Project administration, & Writing - Original Draft; **Ratu Ilma Indra Putri**: Formal analysis, Validation, Supervision; **Zulkardi**: Methodology, Validation, Supervision; **Ely Susanti**: Data Curation and Supervision

References

Almulla, M. (2018). Investigating teachers' perceptions of their own practices to improve students' critical thinking in secondary schools in Saudi Arabia. *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)*, *6*(3), 15–27. https://doi.org/10.5937/ijcrsee1803015A

Apiati, V., & Hermanto, R. (2020). Kemampuan berpikir kritis peserta didik dalam memecahkan masalah matematik berdasarkan gaya belajar [Students' critical thinking ability in solving mathematical problems based on learning styles]. *Mosharafa: Jurnal Pendidikan Matematika*, *9*(1), 167–178. https://doi.org/10.31980/mosharafa.v9i1.601

As'ari, A. R., Kurniati, D., & Subanji. (2019). Teachers expectation of students' thinking processes in written works: A survey of teachers' readiness in making thinking visible. *Journal on Mathematics Education*, *10*(3), 409–424. https://doi.org/10.22342/jme.10.3.7978.409-424

Cazorla, I. M., Utsumi, M. C., & Magina, S. M. (2023). The conceptual field of measures of central tendency: A first approximation. *International Electronic Journal of Mathematics Education*, *18*(4), em0748. https://doi.org/10.29333/iejme/13571

Chukwuyenum, A. N. (2013). Impact of critical thinking on performance in mathematics among senior secondary school students in lagos state. *IOSR J of Research & Method in Education (IOSR-JRME)*, *3*(5), 18–25. https://doi.org/10.9790/7388-0351825

Delina, & Afrilianto, M. (2025). Analysis of mathematical critical thinking skills using differentiation learning on junior high school students based on learning style. *Journal of Innovative Mathematics Learning*, *8*(1), 22–30. https://doi.org/10.22460/jiml.v8i1.p23276

Dewi, D. K., Khodijah, S. S., & Zanthy, L. S. (2020). Analisis kesulitan matematik siswa SMP pada materi statistika [Analysis of junior high school students' difficulties in statistics]. *Jurnal Cendikia: Jurnal Pendidikan Matematika*, *04*(01), 1–7. https://doi.org/10.31004/cendekia.v4i1.148

Facione, P. A. (2013). *Critical thinking: what it is and why it counts*. 1–25.

Franklin, & Mewborn. (2007). Statistics in the elementary grade: Exporing distributions of data. *Teaching Children Mathematics*, *15*(1), 10–16.

Hanifatulianti, F. I., & Sumitro, N. K. (2023). Analisis kemampuan berfikir kritis siswa dalam memecahkan masalah pada materi statistika [An analysis of students' critical thinking ability in solving problems in statistics]. *Jurnal of Millenial Education (JoME)*, *2*(2), 133–146. https://doi.org/10.13189/ujer.2020.080606

Hariri, D. D., Mahmudah, H., Wibawa, F. S., & Kania, N. (2025). Unraveling the connection: A systematic review of learning styles and mathematics achievement. *Pedagogical Research*, *10*(1), em0232. https://doi.org/10.29333/pr/15681

Hikayat, C., Suparman, Hairun, Y., & Suharna, H. (2020). Design of realistic mathematics education approach to improve critical thinking skills. *Universal Journal of Educational Research*, *8*(6), 2232–2244. https://doi.org/10.13189/ujer.2020.080606

Karakoç, M. (2016). The significance of critical thinking ability in terms of education. *International Journal of Humanities and Social Science*, *6*(7). www.ijhssnet.com

Lambertus, E, C., M.R. Saban, M Sudia, M Anggo, & Kadir. (2016). Junior high school students' mathematical critical thinking ability under realistic mathematics approach. *Science International (LAHORE)*, *28*(2), 1377–1382.

Munawwarah, M., Laili, N., & Tohir, M. (2020). Keterampilan berpikir kritis mahasiswa dalam memecahkan masalah matematika berdasarkan keterampilan abad 21 [College students' critical thinking skills in solving mathematical problems based on 21st-century skills]. *Alifmatika: Jurnal Pendidikan dan Pembelajaran Matematika*, *2*(1), 37–58. https://doi.org/10.35316/alifmatika.2020.v2i1.37-58

Nasrulloh, M. F., & Amin, W. F. (2022). Improve critical thinking by developing teaching materials based on realistic mathematics learning. *APPLICATION: Applied Science in Learning Research*, *1*(3), 129–135. https://doi.org/10.32764/application.v1i3.1621

Nova, E., Retta, A. M., & Nopriyanti, T. D. (2022). Student worksheet development using the PMRI approach in the classroom context with an orientation toward students' conceptual understanding. *Jurnal Pendidikan Matematika*, *16*(2), 203–214. https://doi.org/10.22342/jpm.16.2.14854.203-214

Palinussa, A. L. (2013). Students' critical mathematical thinking skills and character: Experiments for junior high school students through realistic mathematics education culture-based. *IndoMS. J.M.E*, *4*(1), 75–94. https://doi.org/10.22342/jme.4.1.566.75-94

Prasetyawan, E. (2018). Keefektifan pendekatan CTL dan discovery ditinjau dari prestasi, kemampuan berpikir kritis dan kecemasan matematika [The effectiveness of the CTL and discovery approaches in terms of achievement, critical thinking ability, and mathematics anxiety]. *Pythagoras: Jurnal Pendidikan Matematika*, *13*(2), 168–180. https://doi.org/10.21831/pg.v13i2.21221

Purwanto, W. R., Waluya, S. B., Rochmad, & Wardono. (2020). Analysis of mathematical critical thinking ability in student learning style. *Journal of Physics: Conference Series*, *1511*(1). https://doi.org/10.1088/1742-6596/1511/1/012057

Putri, S. P., Fajriah, N., & Juhairiah. (2024). Hubungan gaya belajar dan hasil belajar siswa materi statistika pada implementasi kurikulum merdeka [The relationship between learning styles and student learning outcomes in statistics during the implementation of the independent curriculum]. *Jurnal Mahasiswa Pendidikan Matematika*, *4*(1), 47–53. https://doi.org/10.20527/jurmadikta.v4i1.2576

Rahayu, P. T., & Putri, R. I. I. (2021). The data package in learning mean using LSLC and PMRI. *Mathematics Education Journal*, *15*(1), 61–70. https://doi.org/10.22342/jpm.15.1.9431.61-70

Revina, S., & Leung, F. (2019). How the same flowers grow in different soils? The implementation of realistic mathematics education in utrecht and Jakarta classrooms. *Int J of Sci and Math Educ*, *17*, 565–589. https://doi.org/10.1007/s10763-018-9883-1

Sari, D. L., & Nursyahidah, F. (2022). Learning design for statistics materials using the context of traditional market assisted by interactive videos. *Jurnal Elemen*, *8*(1), 29–42. https://doi.org/10.29408/jel.v8i1.4067

Sari, S. N., & Rosyidi, A. H. (2025). Berpikir kritis siswa dalam menyelesaikan masalah matematika kontekstual terbuka ditinjau dari gaya kognitif reflektif dan impulsif [Students' critical thinking in solving open-ended contextual mathematical problems viewed from reflective and impulsive cognitive styles]. *Mathedunesa*, *14*(1), 175–194. https://doi.org/10.26740/mathedunesa.v14n1.p175-194

Siregar, S. (2015). *Statistika terapan untuk perguruan tinggi [Applied statistics for college students]*. Kencana.

Spector, J. M., & Ma, S. (2019). Inquiry and critical thinking skills for the next generation: from artificial intelligence back to human intelligence. *Smart Learning Environments*, *6*(1), 1. https://doi.org/10.1186/s40561-019-0088-z

Subini, N. (2015). *Rahasia gaya belajar orang besar [The secret learning styles of great people]*. PT. Buku Kita.

Sugiyono. (2015). *Metode penelitian kualitatif dan kuantitatif dan R&D [Qualitative, quantitative, and research and development (R&D) methods]*. Bandung: Alfabeta.

Utami, I. D., Fitriyah, L. M., & Indraswari, N. F. (2020). Kemampuan berpikir kritis siswa dalam memecahkan masalah statistika ditinjau dari gaya belajar [Students' critical thinking ability in solving statistical problems viewed from their learning styles]. *Musamus Jurnal of Mathematics Education*, *3*(1), 19–26. https://doi.org/10.35724/mjme.v3i1.3166

Yılmaz-özcan, N., & Tabak, S. (2019). The effect of argumentation-based social studies teaching on academic achievement, attitude and critical thinking tendencies of students. *International Electronic Journal of Elementary Education*, *12*(2), 213–222. https://doi.org/10.26822/iejee.2019257669

Yusuf, Y., R, N. T., & W, T. Y. (2017). Analisis hambatan belajar siswa SMP pada materi statistika [An analysis of junior high school students' learning obstacles in statistics]. *Jurnal Aksioma*, *8*(1), 76–86. https://doi.org/10.26877/aks.v8i1.1509

Zulkardi, & Putri, R. I. I. (2010). Pengembangan blog support untuk membantu siswa dan guru matematika Indonesia belajar Pendidikan Matematika Realistik Indonesia (PMRI) [The development of a support blog to assist Indonesian students and mathematics teachers in learning Indonesian Realistic Mathematics Education (PMRI)]. *Jurnal Inovasi Perekayasa Pendidikan (JIPP)*, *2*(1), 1–24.