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Uncovering metacognitive awareness and meaningful learning of prospective mathematics teachers after learning absolute value inequalities

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ABSTRACT

Learners who lack adequate metacognitive awareness and meaningful have the potential to work mechanically. The aims of this study is to uncover the characteristics and description of metacognitive awareness and meaningful of prospective mathematics teachers after learning absolute value inequalities and the involvement of intuitive and analytical thinking. This study uses a qualitative approach with an exploratory type. A total of 5 prospective mathematics teachers who were taking differential calculus courses were selected as subjects from 87 candidate subjects from two different universities in Indonesia. Data collection was carried out by administering tests and conducting semi-structured interviews. Data analysis in this study went through three stages, namely data reduction, data presentation, and drawing conclusions. The results of data analysis show that: 1) unaware and not meaningful, 2) aware but not meaningful, 3) unaware but meaningful, 4) aware and meaningful. In addition, a pattern of intuitive and analytical thinking was also found, whereby prospective mathematics teachers who were not conscious activated analytical thinking, while those who were conscious activated intuitive thinking. These findings imply the importance of emphasizing mindful and meaningful during the learning process so that students can understand concepts holistically and deeply, enabling them to solve problems accurately.

INTRODUCTION

Research on metacognitive awareness by Tuononen et al. (2023), Çini et al. (2023), Yorulmaz et al. (2021), and Yazici and Dogan (2025) and meaningful learning by Polman et al. (2021), and Andrews et al. (2023). However, these studies have not specifically identified these characteristics in prospective mathematics teachers, particularly in the context of absolute value inequality material. Much research has been conducted on absolute value inequalities, but the characteristics of awareness and meaningful learning in prospective mathematics teachers after studying this material have not been explored in depth. Metacognitive awareness determines whether someone works reflectively or automatically (Tuononen et al., 2023), while meaningfulness determines whether someone works conceptually or merely executes steps (Polman et al., 2021). Thus, someone who learns without awareness and meaningfulness has the potential to work mechanically like a robot. Metacognitive awareness and meaning are two of the three main principles of deep learning that are very important. Reveal that the concept of deep learning is a learning approach that emphasizes the ability to deeply understand the material being studied with the principles of mindful, meaningful, and enjoyable learning. Based on this statement, it is clear that awareness, meaningfulness, and

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enjoyment are at the core of successful deep learning. Therefore, this study focuses on testing two principles of deep learning, namely awareness and meaningfulness.

Metacognition, as introduced by John Flavell in the literature, can be defined as knowledge about cognition in the broadest sense (Yorulmaz et al., 2021).The principle of metacognitive awareness in mathematics learning represents cognitive and affective dimensions that require students to be fully present, aware of their thinking processes, and reflect on each step taken to solve problems. This principle is fundamental and contributes to emotional regulation, full attention to situations and conditions, focus, and increased interpersonal interaction, thereby better preparing students to face the complexity of challenging material (Folch et al., 2023; Hagerman et al., 2023). This contribution indicates that metacognitive awareness functions as a catalyst in activating self-regulation and metacognitive engagement. In line with Folch et al. (2023), Jupri et al. (2022) revealed that metacognitive awareness is not only manifested in attention to material, but also in the ability to associate symbols and meanings, evaluate the appropriateness of approaches, and reflectively recognize the solution strategies used. This shows that active metacognitive awareness in prospective mathematics teachers has the potential to form symbol sense, which is the skill of reading, interpreting, and deeply understanding mathematical symbols and can build a more reflective relationship between symbolic knowledge and conceptual meaning, including on topics that are rich in abstraction such as absolute value inequalities.

Consistently internalized metacognitive awareness will guide prospective teacher students not only to understand mathematical procedures but also to interpret the epistemological value of each thought process they undergo. Several studies reveal that metacognitive awareness encourages students to develop creativity and expand their capacity for critical reflection (Wang & Liu, 2016; Yanko & Yap, 2020). Furthermore, metacognitive awareness strengthens the connection between thoughts, emotions, and actions, enabling students to integrate conceptual understanding with adaptive learning attitudes (Hagerman et al., 2023). In addition, metacognitive awareness also increases curiosity and the ability to cope with stress during difficult times when facing problems, as well as the ability to engage in learning activities (McNulty, 2021; Neff & Germer, 2013; van der Riet et al., 2018). Thus, metacognitive awareness is key to learning success because it enables individuals to integrate conceptual understanding with adaptive attitudes to face challenges in solving mathematical problems (Yorulmaz et al., 2021).

The principle of meaningful learning in deep learning is based on the cognitive learning theory proposed by David Paul Ausubel. Ausubel (1963) revealed that meaningful learning is a process of linking new information with relevant concepts in the cognition of prospective teacher students. This shows that meaningful learning acts as an epistemological pillar that ensures the process of knowledge internalization takes place in a deep, structured, and applicable manner. Furthermore, Andrews et al. (2023), and Michael (2004) state that learning can be considered meaningful if students are able to connect new concepts with knowledge that is already embedded in their cognitive structure, thereby forming a cohesive and adaptive mental representation. Recent research conducted by Andrews et al. (2023) also confirms that meaningfulness not only strengthens long-term retention but also enriches intrinsic motivation, increases active engagement, and expands knowledge transfer abilities. Reflecting on the meaningfulness of learning in mathematics requires students to interpret formal abstractions through conceptual relationships that are continuous with empirical experiences and real-life situations. Therefore, testing the meaningfulness of prospective teacher students after studying absolute value inequalities is an urgent research agenda to measure their conceptual meaningfulness.

The significance of meaning becomes even more prominent when prospective mathematics teachers are positioned not only as algorithm processors but also as epistemic subjects who are required to understand the practical and philosophical values of each mathematical concept. Meaningful learning enables students to construct knowledge independently, integrate abstract ideas with concrete realities, and operationalize them in authentic problem solving. Furthermore, the implementation of contextual, reflective, and collaborative learning strategies has been proven to deepen students' awareness of the relevance of the knowledge they acquire (Folch et al., 2023). Andrews et al. (2023) and Michael (2004) also revealed that the meaningfulness embedded in the learning process has direct implications for students' readiness to build professional teaching competencies oriented towards pedagogical transformation. Thus, this study confirms that meaningfulness as a strategic dimension that must be tested after learning, including learning about absolute value inequalities.

Absolute value inequalities are a very important topic in differential calculus because they require prospective mathematics teachers to integrate and internalize their students' conceptual, procedural, and representational abilities in solving mathematical problems. Research by Nur & Kartini (2021) reveals that students often experience serious difficulties in understanding the definition of absolute value and its application in inequalities, which leads to fundamental and technical errors. These errors include mistakes in identifying relevant information, inability to choose the right solution strategy, and negligence in verifying the final results according to mathematical procedures (Lestari & Roesdiana, 2023). In addition, analysis of the evaluation instruments shows that absolute value inequality questions are still not proportional in terms of difficulty, so they do not fully represent higher-level thinking achievements (Lestari & Roesdiana, 2023; Nur & Kartini, 2021). Therefore, prospective teachers' mastery of absolute value inequalities needs to be critically examined, because conceptual and procedural weaknesses will directly impact the low quality of mathematical representation and the development of pedagogical strategies in the future.

The complexity of absolute value inequalities becomes even more prominent when this material is positioned as a vehicle for developing students' logical, reflective, and analytical thinking skills. Research shows that weak conceptual mastery is often influenced by limitations in learning media and pedagogical strategies that are unable to facilitate active student engagement (Panjaitan & Juandi, 2024). Efforts to develop interactive digital teaching materials and technology-based media have been proven to increase learning motivation, strengthen conceptual understanding, and minimize misconceptions in solving absolute value inequality problems (El-khateeb, 2016; Panjaitan & Juandi, 2024). In addition, empirical studies also confirm that student errors do not only stem from weaknesses in prerequisite knowledge, but also from the inability to connect symbolic abstractions with geometric representations of absolute values as distances on a number line (Nur & Kartini, 2021). Thus, the relevance of absolute value inequalities as an important field for building awareness and meaning for prospective teachers in the framework of intuitive and analytical thinking processes.

Based on this description, the researcher conducted a preliminary study to obtain empirical data to support the theoretical study that had been described. The preliminary study was conducted by giving a small test to seven prospective mathematics teachers in the mathematics education study program in Makassar. The small test given was: "for $x \in R$, what is the solution set of $|x| \leq -2$?" Most of them directly performed procedural operations using the property $|x| < a \Leftrightarrow -a < x < a$ (Verberg et al., 2010). This shows that there are symptoms of metacognitive awareness and meaninglessness as well as the involvement of intuitive or analytical thinking processes in their minds. Therefore, researchers need to explore the intuitive and analytical thinking processes of prospective mathematics teachers while they solve absolute value inequality problems.

Intuitive thinking in mathematics is a non-analytical cognitive process that presents ideas suddenly, instantly, and without following formal procedures (Faizah et al., 2020; Newton et al., 2024; Pytlik et al., 2020). This process functions as a connecting medium that allows individuals to transcend the limitations of algorithmic steps in finding mathematical solutions (Barahmand & Barahmand, 2022). Several studies show that intuition is not only a cognitive shortcut but also the main driver of creative ideas relevant to problem solving (Faizah et al., 2020; Kusumawati et al., 2024). However, mathematics education practices often marginalize intuition due to the dominance of analytical approaches, which are considered more formal and accountable. Therefore, research on the awareness and meaningfulness of intuitive thinking among prospective mathematics teachers is important, especially after they encounter abstract and complex material such as absolute value inequalities.

Intuition used without analytical support has the potential to result in premature decisions. Therefore, intuition needs to be combined with analytical reasoning so that the solutions obtained are valid and comprehensive (Barahmand & Barahmand, 2022; Kusumawati et al., 2024; Newton et al., 2024). The balance between intuition and analysis is a fundamental prerequisite for the formation of complete mathematical competence. evealed that meaningful learning is not only reflected in the mastery of deductive procedures but also in students' ability to synergize intuition with logic when facing complex problem-solving situations. Prospective mathematics teachers are required to develop this ability because the quality of future learning will be largely determined by their ability to integrate intuitive and analytical thinking paradigms. Thus, if intuition can be positioned as a bridge of thought, then the integration of intuition and analysis can be used as an epistemological foundation to test students' awareness and meaningfulness after learning about absolute value inequalities.

Analytical thinking in the field of mathematics education is an intellectual activity that requires students to decompose concepts, identify interrelationships between elements, and formulate conclusions that can be justified logically. This process is not merely a technical skill, but rather an epistemological practice that places reasoning as the foundation for constructing mathematical knowledge structures. Research results show that analytical thinking is a crucial instrument for students to construct systematic mathematical representations and break down the complexity of problems into simpler and more structured forms (Loonsakaewong & Julsuwan, 2025; Yaşar et al., 2025; Yu et al., 2024). However, the low analytical capacity of Indonesian students in solving non-routine problems confirms the gap between procedural mastery and conceptual mastery. This gap makes the study of awareness and the significance of analytical thinking among prospective mathematics teachers after learning absolute value inequalities an urgent and strategic academic issue.

Analytical thinking becomes even more fundamental when prospective teachers are required not only to master algorithmic skills but also to construct valid, coherent, and deductively consistent mathematical proofs (Loonsakaewong & Julsuwan, 2025; Yaşar et al., 2025; Yu et al., 2024). The analytical process allows students to construct arguments by tracing causal relationships, selecting relevant premises, and evaluating the truth of mathematical claims based on applicable definitions and theorems (Loonsakaewong & Julsuwan, 2025; Yaşar et al., 2025; Yu et al., 2024). Thus, analytical thinking has a dual function, namely as a methodological tool in solving mathematical problems and as an epistemological foundation in fostering awareness of the structure of knowledge itself. Students who are able to align analysis with intuition will be better prepared to interpret the meaning of mathematics learning reflectively. Therefore, analytical thinking is positioned as an epistemic framework that builds the meaningfulness of learning for prospective mathematics teachers after they interact with absolute value inequality material.

Based on theoretical studies and empirical supporting data in preliminary studies, there has been no research that focuses on uncover the characteristics and description of metacognitive awareness and meaningfulness of prospective mathematics teachers specifically on the essential topic of calculus, namely absolute value inequalities, while also considering the involvement of intuitive and analytical thinking. Therefore, this study aims to discover the characteristics and description of the metacognitive awareness and meaningfulness of prospective mathematics teachers after learning absolute value inequalities. In addition, this study also reveals the description of the involvement of intuitive and analytical thinking in the metacognitive awareness and meaningfulness of prospective mathematics teachers after learning absolute value inequalities. The results of this study provide important information on the importance of metacognitive awareness and meaningfulness of prospective mathematics teachers after learning mathematical concepts so that they do not work like robots. In addition, this study is also expected to be a source of new knowledge and inspiration for mathematics educators in designing metacognitive awareness and meaningfulness based learning, especially on the topic of absolute value inequalities.

METHODS

This study is an exploratory qualitative study. This method was chosen because the study aims to discover the characteristics and descriptions of the metacognitive awareness and meaningful of prospective mathematics teachers after learning absolute value inequalities and the involvement of intuitive and analytical thinking therein. According to Creswell (2018) and Johnson & Christensen (2020), a qualitative approach is used to explore complex phenomena that are difficult to measure quantitatively, especially when they involve deep thinking and understanding by individuals when

Absolute Value Inequalities	Questions to Test Metacognitive Awareness and Meaningfulness
What is the solution set $$\left|\frac{1}{2}x-3\right| \le -4?$$	

Figure 1. Test Questions to Assess Metacognitive Awareness and Meaningfulness

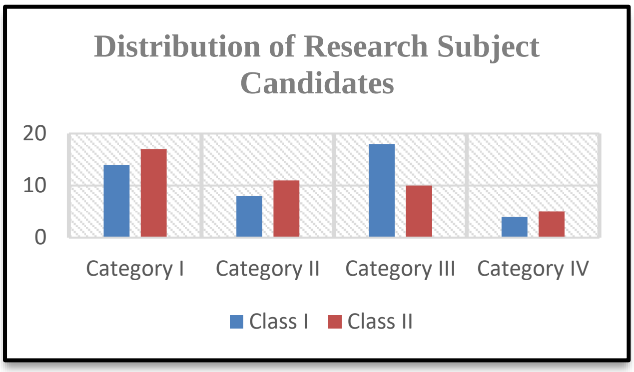

Figure 2. Distribution of Research Subject Candidates

solving problems (Agusman et al., 2025; Rumite et al., 2023). The research subjects consisted of 5 people selected from 87 prospective mathematics teachers who were taking differential calculus courses. Research subjects were selected from each data category to be presented based on the completeness of the data disclosed and their ability to represent other potential subjects. The prospective subjects involved in this study came from several classes at two different universities, namely in Makassar and Lampung. This was done to ensure that the data obtained was saturated and valid. Purposive sampling techniques using absolute value inequality test questions to assess metacognitive awareness and understanding of the learning process. Based on the test results and written responses, the initial data were classified into four categories: 1) unconscious and meaningless, 2) conscious but not meaningful, 3) unconscious but meaningful, and (4) conscious and meaningful.

From each category, one subject was selected purposively, except for the second category which was represented by two subjects, so that the total number of research subjects was five people. The selection of subjects was based on the information-rich principle. Cases, namely the completeness of written data, clarity of responses, and the subject's ability to verbally express their thought processes. The number of subjects was determined based on theoretical saturation, where further analysis no longer yields new characteristics or patterns in each category.

The main research instrument consisted of a single absolute value inequality test item and a semi-structured interview guide. The single item was diagnostic and exploratory, not intended to measure ability quantitatively, but rather to stimulate metacognitive awareness, meaningfulness, and intuitive or analytical thinking tendencies. The item was designed with specific conditions (negative values on the right side) in mind, which conceptually require attention to the meaning of absolute value as distance. Instrument validation was conducted by expert review. Judgment, involving two mathematics education lecturers and one pure mathematics lecturer. Validation focused on the suitability of the questions to the research objectives, the clarity of the mathematical construction, and the questions' potential to reveal awareness and meaningfulness. Instrument improvements were made based on expert input before the test was used in data collection. The absolute value inequality test questions used to collect data in this study are presented in Figure 1.

The absolute value inequality test questions in Figure 1 were developed based on considerations of the possibility of metacognitive awareness and meaningfulness of the problems faced, as well as the involvement of intuitive and analytical thinking processes. The test questions are effective in revealing metacognitive awareness and meaning and the intuitive and analytical thinking processes involved because they allow students to unconsciously and immediately complete the test with the procedural knowledge they understand. They may not be aware of the negative sign

Table 1
Research subjects and prospective subjects

Data Categories	Candidate Subject	Subject
Category 1	31	1
Category 2	19	2
Category 3	28	1
Category 4	9	1
Total	87	5

Table 2
Indicators of awareness, meaningfulness, intuitive thinking, and analytical thinking

No.	Aspect	Indicator
1.	Metacognitive Awareness	✓ Pay attention to the terms and conditions ✓ Pay attention to mathematical signs and symbols
2.	Meaningfulness	✓ Connecting new issues to concepts that have been learned ✓ Revealing the meaning contained in the concept
3.	Intuitive Thinking	✓ Expressing solutions spontaneously ✓ Guessing solutions without following a systematic procedure
4.	Analytical Thinking	✓ Systematically breaking down problems into several parts ✓ Solving problems with systematic procedures

on the right side and cannot express the meaning of the absolute sign as a distance, so they will complete the test like a robot with the procedural abilities they have. In addition, this test will provide input on the importance of emphasizing consciousness and meaning in learning. The research data consisted of 87 interview results and test answer sheets, which were then categorized into four categories as shown in Table 1 and Figure 2.

The data categories are based on differences in the emergence of awareness and meaning, as well as indications of the involvement of intuitive and analytical thinking processes. Category 1, prospective subjects are unaware and do not assign meaning; category 2, prospective subjects are aware but do not assign meaning; category 3, prospective subjects are unaware but assign meaning; and category 4, prospective subjects are aware and assign meaning. Each candidate subject from each data category was selected as a subject based on the completeness of the data disclosed and their ability to represent the data of other candidate subjects. Table 1 shows the number and amount of subjects selected from a number of candidate subjects involved in this study.

The three research subjects were subject 1 (S1), subject 2 (S2), subject 3 (S3), subject 4 (S4), and subject 5 (S5) (pseudonyms). Next, each subject was interviewed semi-structurally for approximately 17 minutes immediately after the subjects completed the test. These interviews were used as triangulation to obtain valid data as described by Creswell (2018), and the interview protocol with generative questions was also used to investigate the subjects' awareness and meaningfulness. During the interviews, all subject responses were recorded on video using a tape recorder and then transcribed. Furthermore, the researcher validated the data by triangulating methods by comparing the data from the test answers, interviews, video recording transcriptions, and relevant documents. In addition, the researcher also conducted member checking by providing the interview results to the subjects to ensure that the researcher's interpretation was in accordance with their experiences. This technique has been proven effective in qualitative research to increase data validity.

Data analysis in this study went through three stages, namely data reduction, data presentation, and conclusion drawing (Creswell, 2018; Miles et al., 2016) with the indicators listed in Table 2. During the data reduction stage, selection, categorization, and focusing were carried out on the exploration of characteristics and descriptions of metacognitive awareness and meaningful, as well as intuitive and analytical thinking. Data reduction was carried out by selecting key points

Table 3
Characteristics of awareness and meaningfulness of prospective mathematics teachers

Characteristics	Awareness	Meaningfulness	Thinking Processes Involved
1.	Unaware	Meaningless	Analytics
2.	Aware	Meaningless	Intuitive
3.	Unaware	Meaningful	Analytics
4.	Aware	Meaningful	Intuitive

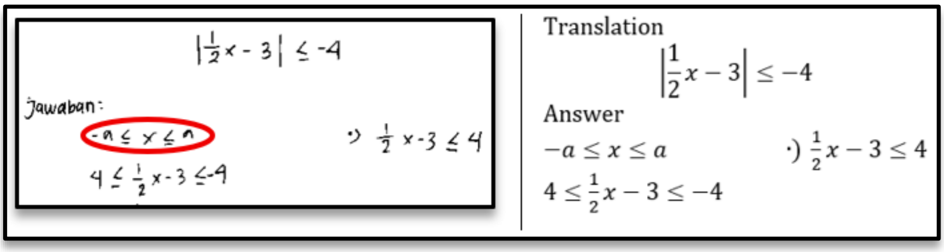

Figure 3. S1's response

and ignoring data that did not play a significant role. Based on the reduction results, the data was then presented according to category and conclusions were drawn.

FINDINGS

The findings show that there are four characteristics and descriptions of metacognitive awareness and meaningfulness among prospective mathematics teachers after learning about absolute value inequalities, including intuitive and analytical thinking involved during the test-taking process. The four characteristics and descriptions are, among others, 1) unconscious and meaningless, 2) conscious but meaningless, 3) unconscious but meaningful, 4) conscious and meaningful. In addition, this study also reveals the involvement of intuitive and analytical thinking in each of the characteristics found. The four characteristics of awareness and meaning among prospective mathematics teachers, along with the thinking processes involved, are presented in Table 3.

Unaware and meaningless

S1 is unaware of the absolute value inequality condition being tested. This unawareness is evident when S1 does not pay attention to the right side of the absolute value inequality being tested. This inattention is demonstrated where the right side of the absolute value inequality being tested contradicts the condition of the bi-implication $|x| < a \Leftrightarrow -a < x < a$. However, S1 still systematically breaks down the problem into several parts and solves the problem with a systematic procedure (shown in Figure 3). This shows that S1 is engaged in analytical thinking. To explore consciousness further, the researcher interviewed S1 as follows.

P : Did you notice anything unusual when completing this absolute value inequality test?
S1 : No.

Based on the description of S1's answer in Figure 3 and the interview excerpt above, it is clear that S1 completely ignored and disregarded the right side of the absolute value inequality, which has a negative value. This means that S1 only memorized the formula $|x| < a \Leftrightarrow -a < x < a$ (shown in Figure 3) and did not reflect on the new situation encountered. Furthermore, the researcher revealed the significance of S1's learning process through the following interview.

P : Can you explain the meaning of absolute value?
S1 : No. I only know that if the value is less than, then use this formula (while pointing to the marked answer in Figure 3)

Based on the interview excerpt, S1 clearly cannot reveal the meaning contained in the concept of absolute value. In addition, S1 indirectly fails to associate absolute value as a distance that cannot be

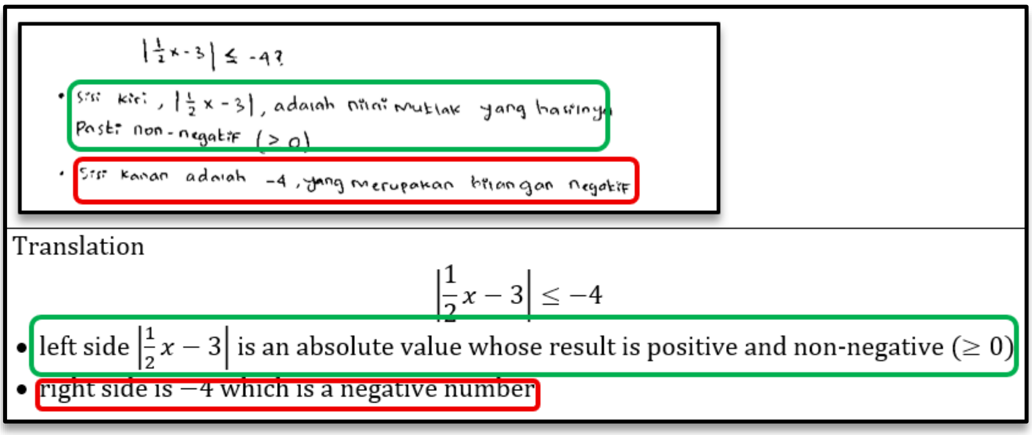

Figure 4. S2's response

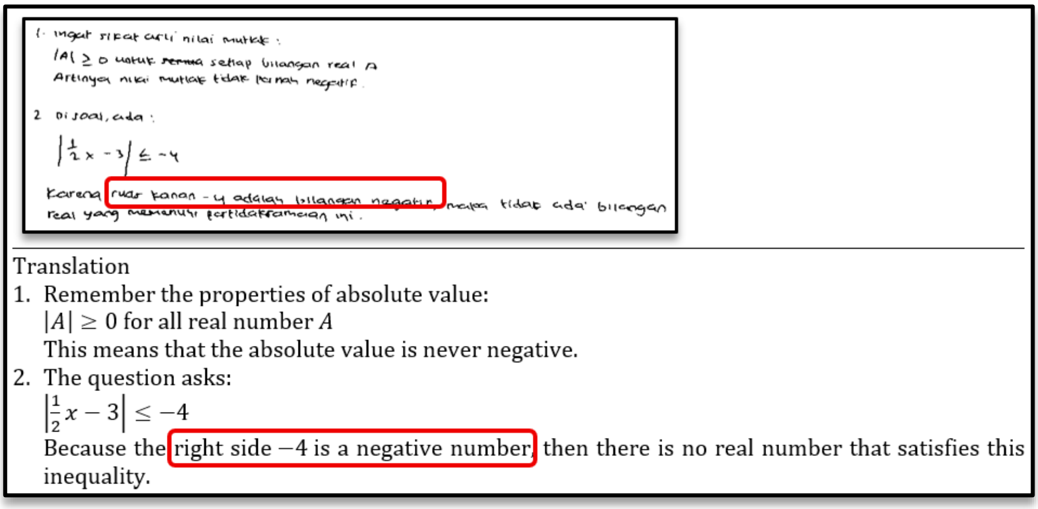

Figure 5. S3's response

negative because the sign in the test question is "≤" and the right side is negative. This shows that the learning process undergone by S1 is meaningless.

Aware and meaningless

S2 consciously pays close attention to the right side of the absolute value inequality being tested. This awareness is evident when S2 explains the negative right side, which indicates negative numbers (shown in Figure 4 marked in red). Furthermore, the researcher explored S2's awareness more deeply through the following interview.

P : *Why don't you use the procedure for solving absolute value inequalities that you learned earlier?*

S2 : *Because the right side is negative, while the formula* $|x| < a \Leftrightarrow -a < x < a$ *can be used if* $a > 0$.

Based on S2's answer in Figure 4 and the interview excerpt above, it is clear that S2 is aware of not ignoring the right side of the absolute value inequality test question, which has a negative value. Based on this awareness, S2 then spontaneously states the solution without performing a systematic procedure, which is a form of intuitive thinking. Furthermore, the researcher revealed the significance of the learning process that S2 had undergone through the following interview.

P : *Do you understand the meaning of absolute value?*

S2 : *The value is always positive or at least zero like this (while pointing to the green-marked answer section in Figure 4).*

Based on the interview excerpts, S2 clearly could not reveal the meaning contained in the concept of absolute value. This shows that the learning process undergone by S2 was meaningless.

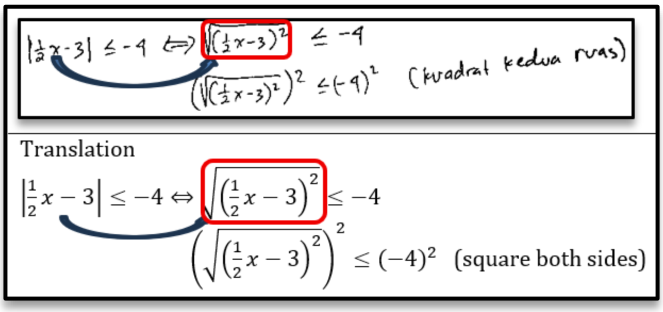

Figure 6. S4's response

S3 consciously pays close attention to the right side of the absolute value inequality being tested. This awareness is evident when S3 explains that the right side consists of negative numbers (shown in Figure 5 marked in red). Furthermore, researchers explored S3 awareness more deeply through the following interviews.

P : Why don't you use the procedure for solving absolute value inequalities that you learned earlier?
S3 : Because the right side of the negative number and the inequality $|x| < a$ applicable $-a < x < a$ if $a > 0$.

Based on S3's answer in Figure 5 and the interview excerpt above, it is clear that S3 is aware of not ignoring the right side of the absolute value inequality test question, which has a negative value. Based on this awareness, S3 then spontaneously states the solution without performing a systematic procedure, which is a form of intuitive thinking. Furthermore, the researcher revealed the significance of the learning process that S3 had undergone through the following interview.

P : Why did you write that? $|A| \geq 0$?
S3 : Because absolute values are always positive.
P : Why is that so??
S3 : emmm... (pause) As far as I remember, that's right..

Based on the interview excerpts, S3 was clearly unable to reveal the meaning contained in the concept of absolute value. This shows that S3's learning was meaningless.

Unaware and meaningful

S4 did not realize the condition of the absolute value inequality being tested. This lack of awareness was evident when S4 did not pay attention to the condition of the right side of the absolute value inequality, which had a negative value. As a result of this oversight, S4 continues to apply the expression $|x| = \sqrt{x^2}$ even though it forces $\sqrt{x^2}$ to be negative because the right side is negative. However, S4 continues to analyze and solve the problem with a systematic procedure (shown in Figure 6). This shows that S4 is engaged in analytical thinking. To explore consciousness further, the researcher interviewed S4 as follows.

P : Can you explain the meaning of absolute value?
S4 : Yes, absolute value is like distance. For example, $|x| > 2$ means the distance from zero is greater than two. Or, for example, $|x - 4| < 3$ means the distance from 4 is less than three.
P : Can you explain further?
S4 : Yes (while writing as shown in Figure 7)

Based on interview excerpts and further explanations as shown in Figure 7, S4 can clearly reveal the meaning contained in the concept of absolute value. S4 interprets absolute value as distance, so in the example $|x| > 2$, S4 reveals that there are two points that are more than two units away from the

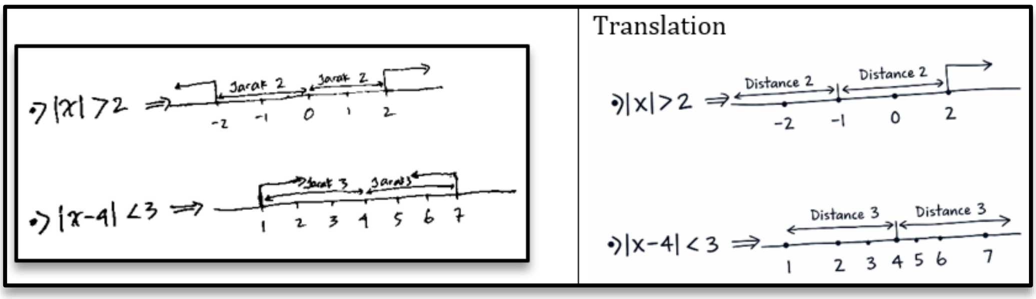

Figure 7. Further Explanation of S4

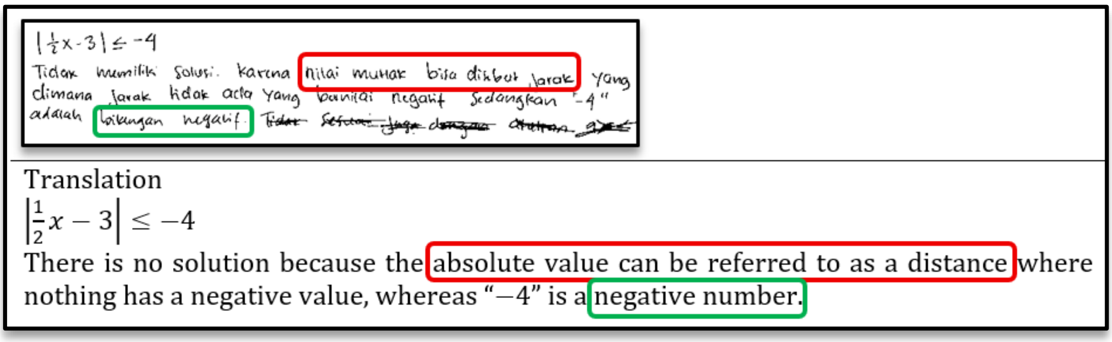

Figure 8. S5's response

zero point, namely -2 and 2. Then, in the example $|x - 4| < 3$, there are also two points that are less than 3 units away from the point 4, namely 1 and 7. This shows that the learning process undergone by S4 is meaningful.

Aware and meaningful

S5 consciously pays close attention to the right side of the absolute value inequality being tested. This awareness is evident when S5 explains that the right side "-4" is a negative number (shown in Figure 8 marked in red). Furthermore, researchers explored S5's awareness more deeply through the following interviews.

P : Why don't you use the procedure for solving absolute value inequalities that you learned earlier?

S5 : Because the right side "-4" is a negative number, while the left side is an absolute value, which I imagine as a distance, and distances are non-negative or always ≥ 0.

Based on S5's answer in Figure 8 and the interview excerpt above, it is clear that S5 is aware of not ignoring the right side of the absolute value inequality test question, which has a negative value. Based on this awareness, S5 then spontaneously states that the solution "has no solution (shown in Figure 8)" without performing a systematic procedure, which is a form of intuitive thinking. In addition, the interview excerpt above clearly shows that S5 can clearly express the meaning contained in the concept of absolute value. In S5's mind, the absolute form is imagined as a distance, i.e., a non-negative value. This shows that the learning process undergone by S5 has been meaningful.

DISCUSSION

This study aims to identify the characteristics and describe the metacognitive awareness and meaningfulness of prospective mathematics teachers after learning absolute value inequalities and the involvement of intuitive and analytical thinking therein. Based on the presentation and analysis of data, S1 and S4 were not conscious when tested on solving absolute value inequalities. This lack of metacognitive awareness was evident when S1 and S4 did not pay attention to the conditions of the inequalities being tested (Folch et al., 2023; Hagerman et al., 2023). S1 ignored the condition $a > 0$ for the validity of the biconditional $|x| < a \Leftrightarrow -a < x < a$ (Verberg et al., 2010), while S4 applied $|x| = \sqrt{x^2}$ and forced $\sqrt{x^2}$ to be negative because the right side was negative (Verberg et al., 2010). This disregard triggers S1 and S4 to engage in analytical thinking by systematically breaking down the problem into several parts and solving the problem with a systematic procedure (Loonsakaewong & Julsuwan, 2025; Yaşar et al., 2025; Yu et al., 2024). In addition, S1 did not interpret the learning process because he was unable to reflect on the new situation he was facing, which certainly contradicted the essence of meaningful learning, which emphasizes linking new concepts with knowledge that is already embedded in his cognitive structure, thereby forming a cohesive and adaptive mental representation (Andrews et al., 2023; Ausubel, 1963; Michael, 2004). However, S4 clearly showed that the learning process was meaningful because he was able to reveal the meaning contained in the concept. This expression is clear when S4 is given the opportunity to explain the meaning of $|x| > 2$. S4 reveals that there are two points that are more than two units away from the zero point, namely -2 and 2, while for $|x - 4| < 3$ there are also two points that are less than 3 away from the point 4, namely 1 and 7.

Furthermore, S2, S3, and S5 were conscious when tested on solving absolute value inequalities. S2, S3, and S5 consciously paid close attention to the negative sign on the right side of the absolute value inequality being tested. This form of full attention and focus on this condition is a basic principle of awareness as expressed by Folch et al. (2023) and Hagerman et al. (2023). As a benefit of this awareness, S2, S3, and S5 were finally motivated to express solutions spontaneously without performing systematic procedures. The behavior of spontaneously expressing solutions without following a systematic procedure, as expressed by S2, S3, and S5, is an intuitive thinking process as expressed by Faizah et al. (2020) and Pytlik et al. (2020). In addition, both S2 and S3 were unable to reveal the meaning contained in the concept of absolute value. This shows that they did not interpret formal abstractions through conceptual relations with empirical experiences. This inability to interpret formal abstractions shows that they fail to reflect on the meaning of learning as expressed. However, unlike S5, who clearly showed that the learning process was meaningful because he was able to reveal the meaning contained in the concept. This expression is clear when S5 imagines the absolute form as a distance, namely a non-negative value.

The results of this study are in line with studies that emphasize the importance of metacognitive skills, including reflective awareness and regulation, in mathematical problem solving (Yorulmaz et al., 2021), where students with higher metacognitive abilities are able to evaluate and regulate their thinking processes more effectively (Folch et al., 2023; Tuononen et al., 2023; Yazici & Dogan, 2025). However, unlike those studies that focused on the general characteristics of metacognition , this study shows that reflective awareness of the meaning of symbols is a key explanatory factor that bridges intuitive and analytical thinking in the context of absolute value inequality, thus broadening the understanding of metacognition in a more specific mathematical domain (Lestari & Roesdiana, 2023; Nur & Kartini, 2021). This finding provides a novel contribution by emphasizing the role of reflective awareness as a cognitive mediator that is not only related to strategy regulation but also to the ability to conceptually understand mathematical symbols. Practically, the implications of this research indicate the need for learning strategies that foster reflection on the meaning of symbols through metacognitive questions and task designs that stimulate reflective thinking. However, the limitations of this study lie in the number of subjects and one material context, so further research is recommended to involve other mathematical contexts and more diverse methodological approaches to strengthen and expand these findings

CONCLUSIONS

The results of the presentation and data analysis show that prospective mathematics teachers are 1) unaware and do not interpret, 2) aware but do not interpret, 3) unaware but interpret, 4) aware and interpret after learning about absolute value inequalities. In addition, a pattern of intuitive and analytical thinking processes was found during the completion of the exam. When prospective mathematics teachers are unaware, the thinking process that is activated is analytical thinking, but conversely, when prospective mathematics teachers are aware, the thinking process that is activated is intuitive thinking. These findings imply the importance of emphasizing awareness and meaning during the learning process so that students can understand concepts holistically and deeply, enabling them to solve problems accurately and not work mechanically like robots.

This study makes a theoretical contribution by confirming the role of reflective awareness as a mediator between intuitive and analytical thinking in symbolic understanding of mathematics. These findings extend the theory of meaningful learning in mathematics education by positioning awareness as a cognitive mechanism that determines the quality of prospective teachers' conceptual understanding. Based Based on the results of this study, prospective mathematics teachers who exhibit characteristics of lack of awareness and lack of meaningfulness need to be provided with in-depth learning that emphasizes the principles of awareness and meaning to improve their awareness and understanding of the concepts being studied. This study has weaknesses in identifying initial abilities and differences in the learning methods and models they use in class. Therefore, this study provides opportunities for further research that considers both of these factors.

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AUTHOR'S DECLARATIONS

Authors' contributions	WR: Contributed to formulating the main ideas, conceptualizing the research, designing the methods, developing the instruments, analyzing the data, interpreting the results, drafting the initial version, finalizing the article, and coordinating the team. HA: Contributed to strengthening the theoretical review, validating instruments, assisting in data interpretation, and revising the substance of the article. SS: Contributed to reviewing, collecting data, organizing data, processing data, presenting data, editing the manuscript, and providing final approval of the version to be submitted.
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