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Adaptive Reasoning of Pre-service Teachers in the Validation of Mathematical Claims

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Abstract. *One of the essential skills that mathematics teachers must possess is the ability to validate mathematical claims before presenting them to their students. Validating mathematical claims requires adaptive reasoning skills. The purpose of this study was to analyze the adaptive reasoning skills of pre-service teachers in validating mathematical claims. The research method used was descriptive qualitative research, employing an adaptive reasoning test and interview guidelines as research instruments. The test was administered to 25 third-semester elementary school student teachers; three responses—one each from a high-performing, a moderate-performing, and a low-performing student—were then selected for further interviews and analysis. The results showed that the lowest achievement rate for adaptive reasoning indicators was in providing justifications (43%), followed by drawing conclusions (57%), and the highest was in reflecting on the problem (77%). Furthermore, the high-ability group was able to correctly validate all mathematical claims on the test, the moderate-ability group was able to correctly validate most of the claims, and the low-ability group was unable to correctly validate any of the claims.*

Keywords: *Adaptive Reasoning, Claims, Mathematics*

INTRODUCTION

Learning mathematics is closely related to reasoning because mathematics is a tool or instrument that requires students to think logically (Bicudo et al., 2023). Reasoning is a cognitive process of drawing conclusions from given information or premises (Pretz & Habibie, 2005).

One type of reasoning required in learning mathematics is adaptive reasoning. Adaptive reasoning refers to the capacity to think logically and reflectively, provide reasons, and offer justifications (Kilpatrick et al., 2001). Adaptive reasoning is not limited to inductive reasoning but also involves deductive reasoning and intuition (Sadiyah & Siswono, 2018). Adaptive reasoning is necessary for justifying and drawing conclusions from a statement or a strategy for solving mathematical problems (Nurlita et al., 2025). Thus, in mathematics learning, it is important to foster adaptive reasoning so that learning becomes more meaningful and understanding becomes deeper. Adaptive reasoning can be fostered

in learning through activities such as verifying the validity of arguments or claims presented in problems, formulating conjectures, identifying patterns, and providing logical justifications for the problem-solving strategies employed (Sadiyah & Siswono, 2018). Furthermore, Valenta et al. explain that *mathematical reasoning* can be understood through how mathematical claims are constructed and validated (Valenta et al., 2024).

A mathematical claim is a statement about mathematical objects or their relationships, the truth of which can be proven through deductive reasoning (Valenta et al., 2024). The process of formulating claims involves adaptive reasoning because it involves activities such as comparing, classifying, identifying patterns, making generalizations, and *conjecturing,* whereas the process of proving claims involves evaluating why a step is valid, assessing the truth of the claim, and reflecting on and refining one's own line of reasoning (Lessing & Ogbonnaya, 2025). Furthermore, proving and validating mathematical claims requires adaptive reasoning skills to identify logical errors or conceptual flaws in the claim and to persevere in proving it (Ismailov et al., 2026). In addition, adaptive reasoning skills are flexibly used to revise and refine mathematical claims to arrive at the correct conclusion (Pepin et al., 2025). The results of the study by Putri et al. show that students' ability to validate claims through adaptive reasoning achieved the lowest score of 45.97% (Putri & Muhandaz, 2026). This is consistent with the study by Zahrah et al., which showed the lowest achievement in the validation of mathematical claims at 28.95% (Zahrah & Muhandaz, 2026).

.A literature review by Lessing et al. indicates that students' difficulties in mathematical reasoning and proof stem from their teachers' lack of confidence or insufficient knowledge in these areas, which limits their ability to develop and teach these skills to their students (Lessing & Ogbonnaya, 2025). Furthermore, the results of a literature review by Nurlita et al. indicate that pre-service teachers demonstrate greater mastery of strategic skills in solving procedural problems than in adaptive reasoning related to the mathematics content they are taught, making it a real challenge to develop pre-service teachers' mastery of adaptive reasoning (Nurlita et al., 2025).This is because pre-service teachers will eventually become teachers

who, before teaching, will read various learning resources to prepare what they will teach their students. These learning resources contain the concepts of the material to be presented. They must be able to correctly verify the truth or validity of these concepts before presenting them to their students. Additionally, they are also expected to be able to formulate valid mathematical claims before presenting them to their students.

Based on the above discussion, the researchers conducted further research on pre-service teachers' adaptive reasoning in the formulation and validation of mathematical claims. Studies on pre-service teachers' reasoning have focused on their ability to construct and evaluate arguments, provide justifications, and determine the validity of mathematical statements. Zeybek Simsek's research examined how pre-service teachers determine the truth of statements and verify students' arguments (Zeybek Simsek, 2021). In addition, Makowski examined written and oral forms of justification for mathematical claims (Makowski, 2021). These studies have examined pre-service teachers' ability to verify mathematical statements, evaluate students' arguments, and construct justifications. However, these processes have not been analyzed from the perspective of adaptive reasoning to examine how reflection, justification, and conclusion-drawing are interrelated when prospective teachers validate mathematical claims. The results of the literature review by Lessing et al. indicate that pre-service teachers are weak in reasoning and proof, but these findings are based on final answers (Lessing & Ogbonnaya, 2025). Furthermore, Syukriani et al. studied the adaptive reasoning of prospective mathematics teachers, focusing solely on the analysis of strategic competencies—specifically, formulation and representation—in solving a single mathematical problem (Syukriani & Juhari, 2025).This study not only examines the adaptive reasoning reflected in the final answers and the strategic competencies of pre-service teachers but also further analyzes how they formulate and validate mathematical claims regarding the two given mathematical problems.

RESEACH METHOD

The research method used was descriptive qualitative research, with the aim of describing the adaptive reasoning of *pre-service elementary school teachers* with high, moderate, and low abilities in forming and validating mathematical claims. The research subjects were 27 third-semester elementary school teacher candidates at the Al Fithrah Institute in Surabaya who were taking an advanced elementary school mathematics course. All subjects were administered an adaptive reasoning test, after which three were selected for interviews and further analysis. Subject selection employed purposive sampling, with students first grouped into three categories—high, moderate, and low—based on their grades in the elementary school basic mathematics course. Next, one student with the most complete responses was selected from each group so that the researcher could obtain a representative picture of how they engaged in adaptive reasoning to formulate and validate mathematical claims. The data collection instruments used were a test containing indicators of adaptive reasoning and an interview guide. The data analysis technique employed the interactive method developed by Miles and Huberman, which consists of data reduction, data interpretation, and drawing conclusions (Abdussamad, 2021).

Table 1. Indicators of Adaptive Reasoning

Key Indicator	Operational Indicators
Ability to reflect	Students are able to review anda identify the accuracy or inaccuracy of mathematical information or statement.
Ability to justify	Student are able to formulate logical reasons, evidence, or arguments to support each step and formula used in problem solving.
Ability to Thank logically (drawing conclusion)	Students are able to draw conclusions or make final decisions based on the results of their reflection and justufication.

The key indicators of adaptive reasoning, based on a *systematic literature review* by Nurlita et al., include logical thinking, problem-solving skills, reflection and justification, as well as creativity and intuition (Nurlita et al., 2025). This study

selected logical thinking, reflection, and justification as the key indicators and then developed operational indicators as table 1..

The percentage of achievement for the adaptive reasoning indicator is as follows (Miatun & Ulfah, 2023).

Table 2. Criteria for indicator achievement intervals

Percentage Range	Category
86 - 100	Very high
76 - 85	High
60 - 75	Moderate
55 - 59	Low
0 - 54	Very low

RESULT AND DISCUSSION

An adaptive reasoning test was administered to 25 prospective elementary school teachers who were taking an advanced mathematics course. The following is a summary of the achievement levels for the adaptive reasoning indicators among all research participants.

The results to table 3, of the three indicators, the highest score was achieved in the ability to reflect, while the lowest was in the ability to justify. This indicates that most students are already capable of reflecting, although they still struggle to move from their reflections to the stage of justification or drawing conclusions. This indicates that students are able to identify inconsistencies in a statement or make a decision regarding a claim, but are not necessarily able to explain the mathematical basis for that decision. This pattern aligns with the findings of Öztürk and Güven, who showed that the evaluation of evidence involves various criteria, and that the ability to validate a claim cannot be separated from the quality of the justification used (Öztürk & Güven, 2022). Difficulty in constructing justifications was also a

finding by Haavold et al., who noted that some pre-service teachers validate evidence empirically and view a convincing argument as a good one even when the mathematical reasoning supporting that argument is not yet sufficiently strong (Haavold et al., 2024). This finding suggests that the decision to accept or reject an argument may arise before students have a strong foundation for justification.

Table 3. Achievement of research subject indicators

Operational Indicators	Percentage Range	Category
Students are able to review and identify the accuracy or inaccuracy of mathematical information or statements	77%	High
Students are able to formulate logical reasons, evidence, or arguments to support each step and formula used in problem-solving	43%	Very low
Students are able to draw conclusions or make final decisions based on the result of their reflection and justifications	57%	Low

Furthermore, students were better able to draw conclusions than to provide justifications. They were able to write down formulas correctly but had difficulty providing reasons and drawing conclusions. This suggests that much of their reasoning is procedural—relying on memorizing formulas rather than deriving meaning from them (Ningtyas, 2026). Next, three answer sheets—one each from a high-ability, medium-ability, and low-ability student—were selected to proceed to the interview stage for further analysis. Students' answers were marked in red to indicate achievement of the first indicator, yellow for the second indicator, and blue for the third indicator. The following is a description of the results for these three students

1. Adaptive Reasoning for High-Ability Students (S1)

   Here is the S1 answer sheet

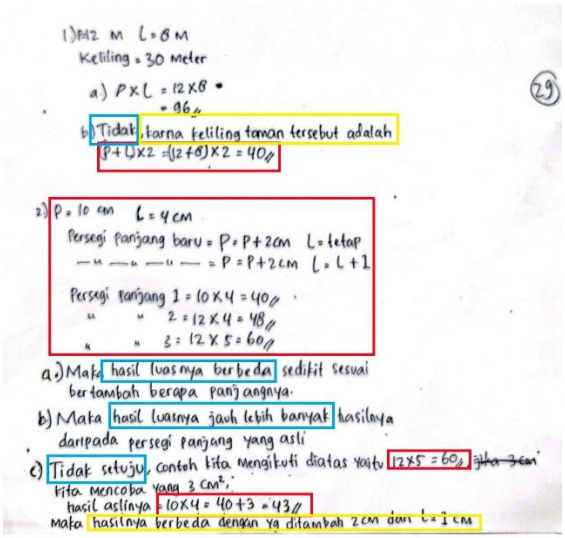


Figure 1. S1 Answer Sheet

A further analysis of the S1 responses based on the adaptive reasoning indicator in claim construction is as follows.

a. Reflection

S1 double-checks the information provided in the problem. He further verifies the perimeter of the park in problem 1 by recalculating it. In question 2, S1 compared the area before and after the increase by writing out the mathematical calculations for the area at each change in dimensions. Additionally, S1 tested the claim in question 2c by verifying whether the area of a rectangle with a length of 12 and a width of 5 is equal to the area of the first rectangle plus 3.

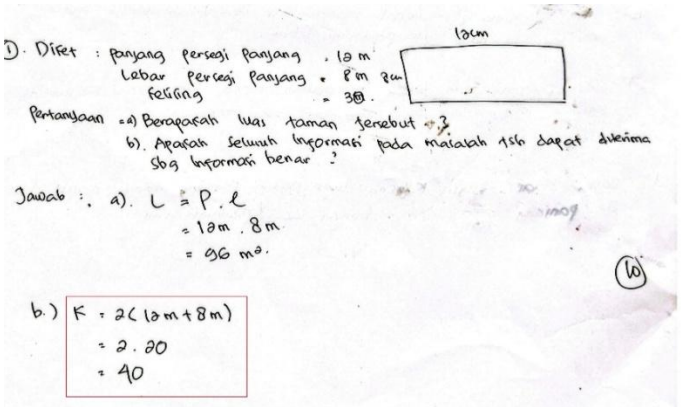
b. Justification

In Question 1, S1 used mathematical calculations to show that the perimeter of the garden should be 40 cm. On the answer sheet, for Question 2, S1 only wrote the conclusions “the area is slightly different” and “the result is much larger” without providing a mathematical justification for the difference in area. However, when asked during the interview about the meaning of “slightly different” and “the result is much larger,” S1 provided a mathematical calculation of the difference in area: “The area of the second rectangle is 8 more than that of the first rectangle, and the area of the third rectangle is 10 more than that of the second rectangle”.

c. Conclusion

For question number 1, S1 was able to conclude that the perimeter information in the question was incorrect. However, on the answer sheet for question 1, S1 wrote in the order of conclusion, justification, and then reflection. For the claim validation question number 2, the order in which Student 1 wrote on the answer sheet was conclusion, reflection, and justification. During the interview, it was revealed that Student 1 actually began working on the question with mathematical calculations—or the reflection stage—but wrote the conclusion first on the answer sheet because they were confused about the correct order for writing answers on the sheet. Furthermore, for questions 2a and 2b, Student 1 was able to conclude that the areas were different and was able to conclude that they disagreed with the claim in question 2c. Student 1 was able to draw conclusions even though they were not fully written out on the answer sheet. During the interview, Student 1 was also able to clarify the conclusion written on the answer sheet, explaining that the increase in the area of a rectangle depends on the increase in the lengths of the rectangle's sides.

2. Adaptive Reasoning in Students with Moderate Abilities (S2)



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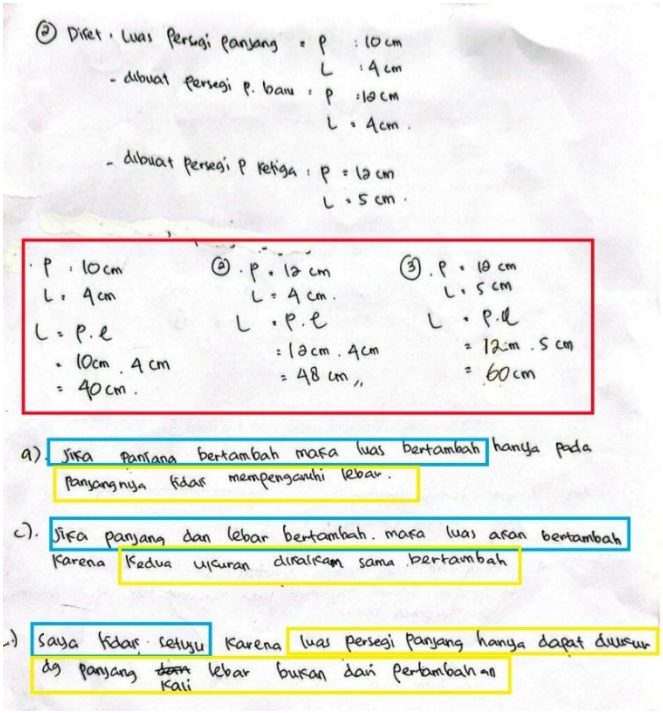


Figure 2. S1 Answer Sheet

a. Reflection

Student S2 in question 1 also double-checked the given information—specifically, the perimeter of the rectangle—by plugging the known length and width into the formula for the perimeter of a rectangle. Student S2 in question 2 also checked the change in area for each increase in size and accurately wrote the calculations on the answer sheet. Student S2 in question 2c read the claim and then reviewed the area of the rectangle. This step was not written on the answer sheet. During the interview, S2 said: "After reading question 2c, I thought the area of a rectangle is length times width; there's no increase."

b. Justification

For question 1, after finding the correct perimeter, S2 did not write anything else on the answer sheet. When asked during the interview why he wrote the perimeter calculation on the answer sheet, S1 said, "The correct perimeter is 40 cm, not 30 cm." S2 only wrote "the area increases" without providing a clearer justification. However, when asked during the interview what "the area increases" meant, S2 pointed to the mathematical calculation of the difference in area on his answer sheet: "If the dimensions change, the area also increases." "Even if only one

of them changes in size—like the second rectangle—the area also increases, from 40 to 48. If both change in size, the area also increases, just like the third rectangle, which has an area of 60." For question 2c, S2 provided an inaccurate justification, stating that the area of a rectangle can only be calculated by multiplying the length and width.

c. Conclusion

In question 1, Student 2 did not write a conclusion regarding the information provided in the question. However, during the interview, when asked what could be concluded from the answer to 1b that he had written, he was able to respond, "That means the perimeter given in the question is incorrect. It should be 40 m, not 30 m." For questions 2a and 2b, S2 was able to correctly write the conclusions regarding the changes on the answer sheet, although the sentences still need improvement. For question 2c, S2 drew the correct conclusion—that they disagree with the claim—even though the reasoning or justification provided was not entirely accurate.

3. Adaptive Reasoning in Students with Low Academic Ability (S3)

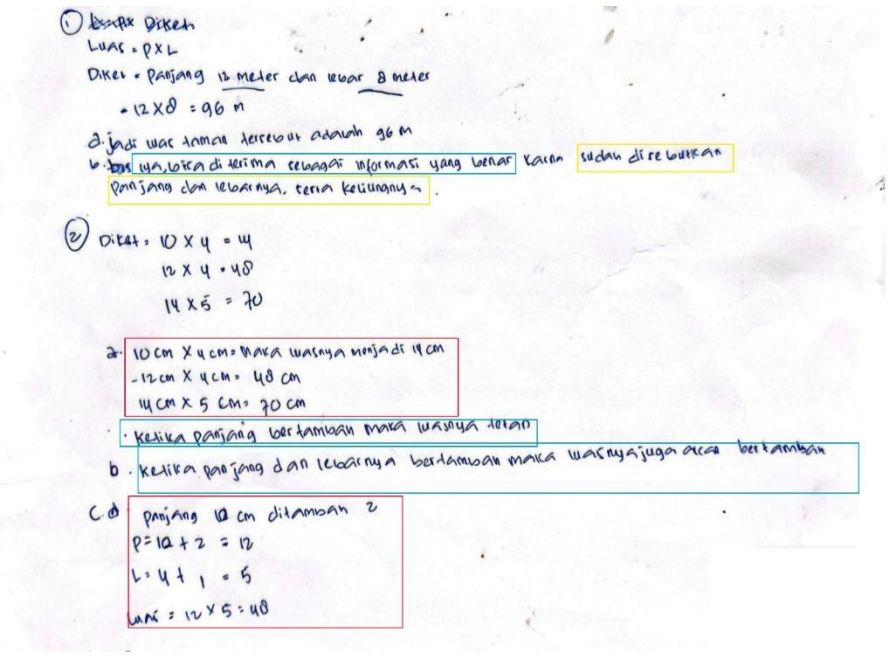


Figure 3. S3 Answer Sheet

a. Reflection

During the interview, S3 stated that he reread question number 1 and then agreed with the information provided. He did not, like S1 and S2, double-check the perimeter of the rectangle using mathematical calculations. During the interview, S3 said, "I've reread the information in the question, and there's nothing unusual." For questions 2a and 2b, S3 also performed calculations to verify the changes in the area of each rectangle and wrote the results on the answer sheet, but the calculations were not entirely accurate. He wrote that the area of a rectangle with a length of 10 cm and a width of 4 cm is 14 cm. S3 tested the claim in question 2c by calculating the area of the rectangle if the length increased by 2 and the width increased by 1. The calculation he obtained was incorrect. The result should have been 60, but he wrote 48.

b. Justification

After rereading the information for question 1, S3 justified that none of the given information in the question was incorrect. When asked about the perimeter, he replied, "It's fine; the question asks for the area of the rectangle. You don't need the perimeter to calculate the area." For question 2, S3 struggled to provide a justification because he made a mistake in calculating the area of the rectangle when the length and width were increased. During the interview, he was unable to provide a justification for his incorrect calculation and immediately drew a conclusion.

c. Conclusion

For question 1, S3 was able to draw a conclusion on the answer sheet, although the conclusion was incorrect. This was because he did not recalculate the perimeter of the rectangle. For question 2, S3 drew a conclusion without providing a justification. For the second rectangle in question 2a, he wrote an incorrect conclusion on the answer sheet, namely "the area remains constant," whereas for 2b and 2c, he wrote the correct conclusions on the answer sheet but was unable to explain or provide a rationale.

Based on the results of the analysis of the three subjects with different abilities described above, it was found that all subjects were able to formulate reflections using the formulas for the area and perimeter of a rectangle. One contributing factor

was that the research subjects had already studied the material covered in the adaptive reasoning test during the previous semester in their basic mathematics course. However, Subject S3 was not thorough enough in examining the information in Question 1 and made a calculation error in Question 2.

Subjects S1 and S2 were able to provide justifications, although S1 did not write out the justification process and S2 provided only a brief justification on the answer sheet. However, they were able to explain their reasoning during the interview. They had difficulty writing out their justifications on the answer sheet. Meanwhile, Subject S3 was unable to provide a justification and jumped directly to a conclusion. Furthermore, S1 and S2 were able to draw accurate conclusions based on proper reflection and justification. Meanwhile, S3 was able to draw two accurate conclusions without providing justification—due to incorrect reflection—and two illogical conclusions. S3 was also unable to explain the conclusions drawn because the mathematical calculations performed during the reflection stage were inaccurate. The results of the study by Miatun et al. indicate that prospective teacher students make incorrect conclusions due to errors in initial calculations resulting from memorizing procedures without conducting further conceptual analysis when formulating evidence for their claims (Miatun & Ulfah, 2023). This results in conclusions drawn haphazardly without providing logical reasoning or supporting evidence (Sofyana & Kusuma, 2018). Furthermore, conclusions are drawn without justification because students are already convinced by relying solely on numerical calculations during the reflection process. Pre-service teachers tend to formulate or validate claims based solely on numerical calculations and skip the justification stage when constructing logical arguments from the results of their reflections (Purnomo et al., 2026).

The findings from the answer sheets indicate that the research subjects did not provide complete answers that met all three indicators. However, during the interviews, they were able to provide complete answers that met all three indicators of adaptive reasoning. For example, Subject S1 in questions 2a and 2b did not write logical reasons that met the justification indicator but was able to write a conclusion, and Subject S2 in question 1 only wrote the reflection process—that is,

recalculating the perimeter of the rectangle—without providing justification or a conclusion. However, during the interview, they were able to describe their problem-solving process in full detail, along with logical arguments, enabling them to arrive at a conclusion that was not written on the answer sheet. These findings are consistent with Makowski's work, which revealed differences between the written and oral justifications of prospective mathematics teachers (Makowski, 2021). A similar pattern is also reflected in Malambo's study, which used written responses and interviews to capture the prospective teachers' explanations and justifications more comprehensively (Malambo, 2023). Magiera and Zambak also emphasize that mathematical reasoning can be communicated in various forms, so the mode of presentation can influence the observable aspects of reasoning (Magiera & Zambak, 2021). This aligns with the findings of Miller et al., who noted that students are often able to find the correct answer to a math problem but struggle to write down the steps or logical reasoning on the answer sheet. Some of the reasons for this include students feeling that what they wrote on the answer sheet was already clear enough for the reader to understand, a focus on the final answer, and difficulty putting their thoughts into words on the answer sheet (Miller et al., 2023).

Furthermore, reflection, justification, and conclusion are not rigid, sequential stages but rather dynamic processes. All subjects began the test by reflecting on their mathematical calculations; subsequently, some drew conclusions first and then provided justifications (e.g., Subject 1), while others provided justifications first and then drew conclusions (e.g., Subject 2). The stages or processes an individual uses to validate mathematical claims may differ from those of others due to variations in the structure and number of claim cases within the problem, as well as differences in the initial approach to constructing reflections (Valenta et al., 2024). Furthermore, analysis of the responses revealed that S1 successfully validated the claim, S2 successfully validated most of the claims, while S1 was unsuccessful. A person's success in validating claims is influenced by the depth of their conceptual understanding (Ismailov et al., 2026). Mukuka and Tatira attribute students' difficulty in constructing valid proofs to weaknesses in conceptual understanding,

including confusion regarding mathematical definitions, proof methods, and the use of variables (Mukuka & Tatira, 2025). Students with insufficient conceptual understanding will hinder the claim validation process, leading them to reach incorrect conclusions (Lessing & Ogbonnaya, 2025).

CONCLUSION

The achievement rate for the adaptive reasoning indicators among prospective elementary school teachers was 77% in the "high" category for the reflection indicator, 57% in the "low" category for the drawing conclusions indicator, and 43% in the "very low" category for the providing justifications indicator. All subjects were able to engage in reflection involving the calculation of the area and perimeter of a rectangle, although Subject S1 made a mistake in the mathematical calculation due to a lack of attention to detail. Furthermore, most participants did not write down the process or justification on the answer sheet because they were unsure how to do so. Additionally, the research results showed that the stages of the mathematical claim validation process were not uniform across all participants. In other words, reflection, justification, and conclusion are dynamic and do not follow a fixed sequence. Furthermore, the validation of a claim yields a correct conclusion when reflection, justification, and drawing a conclusion are all carried out.

This study was conducted with elementary school teacher candidates, and the problems used involved the area and perimeter of two-dimensional shapes that had been studied in the previous semester. Future research could analyze the validation of claims in other topics not yet studied in the previous semester and could also use student participants.

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