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Visual Observation and Metacognitive Regulation Errors in Geometry Problem: An Analysis of Secondary Students' Thinking

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Abstract: *This study analyzes secondary students' errors in visual observation and metacognitive regulation while solving geometry problems involving triangles and quadrilaterals. Using a descriptive qualitative approach, three students representing high, moderate, and low mathematical ability levels demonstrated distinct error types. Students with high mathematical ability showed accurate visual observation and effective planning and monitoring but frequently neglected the evaluation stage. Students with moderate ability missed several visual cues and made errors in monitoring and evaluating their solutions. Those with low ability struggled across all indicators, showing minimal visual observation and multiple metacognitive regulation errors. Although all students performed basic visual observation, none carried out deep and critical evaluation. This study is limited by the small sample size, which restricts generalizability. Future research should involve larger and more diverse participants and examine instructional interventions designed to strengthen students' visual observation and metacognitive regulation skills in geometry learning.*

Keywords*: visual observation, metacognitive regulation errors, geometry, triangles, quadrilaterals, students' mathematical ability*

Abstrak: Penelitian ini menganalisis kesalahan siswa sekolah menengah ketika melakukan pengamatan visual dan regulasi metakognitif ketika menyelesaikan masalah geometri yang melibatkan segitiga dan segi empat. Dengan menggunakan pendekatan deskriptif kualitatif, tiga siswa yang mewakili kemampuan matematis tinggi, sedang, dan rendah menunjukkan jenis kesalahan yang berbeda. Siswa dengan kemampuan tinggi mampu melakukan pengamatan visual dengan tepat serta menunjukkan perencanaan dan pemantauan yang baik, tetapi sering mengabaikan tahap evaluasi. Siswa dengan kemampuan sedang melewatkan beberapa detail visual dan melakukan kesalahan pada tahap pemantauan dan evaluasi. Sementara itu, siswa dengan kemampuan rendah mengalami kesulitan pada semua indikator, menunjukkan pengamatan visual yang minimal dan berbagai kesalahan regulasi metakognitif. Meskipun semua siswa melakukan pengamatan visual dasar, tidak ada yang melakukan evaluasi secara kritis dan mendalam. Penelitian ini memiliki keterbatasan pada ukuran sampel yang kecil sehingga temuan tidak dapat digeneralisasikan. Penelitian selanjutnya perlu melibatkan lebih banyak peserta yang beragam serta menguji intervensi pembelajaran untuk meningkatkan keterampilan pengamatan visual dan regulasi metakognitif siswa dalam pembelajaran geometri.

Kata kunci: pengamatan visual, kesalahan regulasi metakognitif, geometri, segitiga, segiempat, kemampuan matematika siswa

INTRODUCTION

Geometry is a fundamental branch of mathematics that examines shapes, sizes, positions, and spatial relationships, which include basic components such as points, lines, and planes (Ajmera, 2020). Geometry instruction is provided at every schooling level because of its importance in developing students' visual–spatial reasoning, problem-solving abilities, and logical thinking (Anwar & Juandi, 2020).

Within geometry learning, visual observation refers to students' ability to perceive, interpret, and analyze visual information such as diagrams, spatial relationships, and geometric symbols. Strong visual observation enables students to identify key information and translate visual cues into appropriate strategies (Danial et al., 2024; Haataja et al., 2025). Meanwhile, metacognitive regulation refers to students' awareness and control over their thinking processes, particularly the stages of planning, monitoring, and evaluating (Al-Adwan & Al-Debei, 2024; Stanton et al., 2021). Students with effective metacognitive regulation tend to choose strategies more accurately, check their progress, and critically reflect on their solutions (Thi-Nga et al., 2024).

Although geometry is considered basic material, many students still struggle with it. Interviews with a junior high school mathematics teacher in Surabaya showed that approximately 40% of students frequently make mistakes when working on problems involving plane figures, especially unfamiliar or combined shapes. These errors suggest weaknesses in interpreting visual information and in regulating thinking processes two components closely related to visual observation and metacognitive regulation (Fastame, 2021; Wangguway et al., 2025)

Previous studies have examined these aspects but tend to treat them separately. (Rajapakse et al., 2024; Septiani et al., 2020) investigated students' visual observation skills without linking them to metacognitive processes. Conversely, Wangguway et al. (2025) focused on students' metacognitive regulation but did not integrate visual observation into the analysis. As a result, existing research provides only a partial understanding of the difficulties students face when solving geometry problems.

Until now, no study has simultaneously analyzed students' visual observation and metacognitive regulation during geometry problem solving, particularly in tasks involving multiple interconnected shapes such as triangles and quadrilaterals.This gap limits understanding of how perceptual accuracy and metacognitive control interact to influence students' geometric reasoning.

Therefore, this study aims to provide an in-depth description of students' visual observation errors and metacognitive regulation errors when solving geometry problems involving triangular and quadrilateral shapes. A descriptive qualitative approach was chosen because it allows researchers to explore students' reasoning processes naturally through written work and interviews. The findings of this research are expected to contribute to improving geometry learning by identifying specific difficulties experienced by students in both visual and metacognitive aspects.

METHOD

Research Design

This study employed a descriptive qualitative design aimed at exploring students' visual observation and metacognitive regulation processes during geometry problem solving. A qualitative approach was chosen because it enables researchers to capture students' natural reasoning patterns, thought processes, and cognitive strategies in depth through written responses and interviews (Creswell & Creswell, 2022). Moreover, this method allows the researcher to examine students' thinking processes in a natural context, including how they observe visual information, plan strategies, monitor their steps, and evaluate their resultsprocesses that cannot be fully represented through numerical data.

By uncovering the underlying reasons behind each error, this approach provides a deeper understanding of the dynamics of metacognitive regulation and visual observation during geometry problem solving.

Participants

This study was conducted in a public junior high school located in Surabaya, Indonesia. The school implements the national Curriculum 2013 (K13), which emphasizes problem-based learning and higher-order thinking skills. Mathematics instruction commonly integrates visual representations and diagram interpretation, making it a relevant setting for examining students' visual observation and metacognitive regulation processes. The learning environment also reflects typical classroom conditions in Indonesian junior high schools, allowing the findings to represent common challenges faced by students when solving geometry problems.
Participants were eighth-grade students who had previously studied basic concepts of plane geometry, including properties of triangles and quadrilaterals. Students were selected using purposive sampling based on the following criteria:

1. Students had basic arithmetic proficiency
2. They understood fundamental properties of plane figures, and
3. They were able to communicate their reasoning clearly.

Three students were chosen to represent different mathematical ability levels. Their ability categories were determined using mathematics scores from grade 7 to grade 8, which were obtained from school records and calculated as cumulative averages. The classification followed Mulyadi and Manoy (2022):

1. High ability (80–100),
2. Moderate ability (60–79.9), and
3. Low ability (0–59.9).

Student RSD (average score: 76) as moderate-ability, and Student CAG (average score: 52.5) as low-ability. Using the same mathematics teacher for both academic years ensured consistent and comparable assessment across students.

Although the sample size consisted of only three participants, it allowed for an in-depth examination of individual reasoning processes. However, this also limits the generalizability of the findings. Future research may expand the sample across multiple schools to enhance external validity and representativeness.

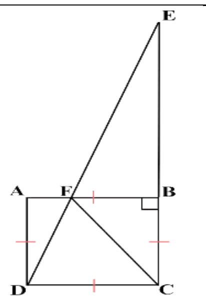
Research Design and Procedure

This research design uses a descriptive qualitative method. According to (Creswell & Creswell, 2022), descriptive qualitative research is a way of exploring and explaining a phenomenon or data in oral or written form and then describing it (Anderson & Dexter, 2020). This research consists of three stages, namely preparation, implementation, and data analysis

Instruments

Two main instruments were used in this study: a geometry test and semi-structured interview guidelines. The geometry test was designed to assess students' visual interpretation and conceptual understanding in solving problems involving combined plane figures, specifically triangles and quadrilaterals. The test consisted of one open-ended question that required students to identify component shapes, interpret spatial relationships, and apply appropriate geometric formulas. This type of question allowed the researcher to observe variations in students' reasoning and problem-solving strategies across different ability levels (Hidayat et al., 2023)

The semi-structured interview guidelines were developed to obtain deeper insights into students' cognitive and metacognitive processes during problem solving. The interviews focused on how students interpreted the visual information, selected strategies, monitored their solution steps, and evaluated their answers. This instrument also helped clarify written responses and reveal misconceptions or reasoning steps that were not visible through the test alone (Galitskaya et al., 2024)). Together, the geometry test and interview guidelines provided complementary data that enabled a comprehensive analysis of both the accuracy of students' solutions and the underlying reasoning and metacognitive regulation involved in solving the geometry problem. Geometry problem used in the study is shown in figure 1, illustrating the spatial relationships required to analyze students' visual observation and metacognitive processes.



Look at the picture!
The perimeter of region ABCD is 16 cm, and the length of CE is three times the length of BC.
Determine the area of triangle ECF!

Figure 1. Geometry problem used in the study, illustrating the spatial relationships required to analyze students' visual observation and metacognitive processes.

Data Analysis

The data analysis in this study followed the qualitative analysis model proposed by (Creswell & Creswell, 2022), which includes several systematic stages: preparing the data, reading all data, coding the data, identifying themes or categories, interpreting the findings, and drawing conclusions. This structured process ensured that the data were examined comprehensively and meaningfully, allowing the researcher to uncover patterns and insights related to students' mathematical thinking and metacognitive processes. The analysis process began with the administration of the geometry test to the three selected subjects, each representing a different level of mathematical ability (high, moderate, and low). The test activity lasted approximately 15 minutes, during which students completed an open-ended problem involving combined geometric shapes. After the completion of the test, the researcher collected all written responses and proceeded to conduct individual interviews with each subject in turn. These interviews were aimed at exploring the students' reasoning steps, problem-solving strategies, and self-monitoring behaviors during the test.(Al-Adwan & Al-Debei, 2024)

Data from the tests and interviews were transcribed, organized, and systematically coded to identify meaningful patterns. The researcher then grouped these findings into thematic categories centered on students' visual observation abilities and metacognitive regulation errors. These two themes became the core focus of the analysis, providing a framework for understanding how students perceived geometric relationships and managed their thinking processes while solving geometry problems (Herliandry et al., 2020). The coding process focused on identifying students' visual observation indicators and metacognitive regulation errors to analyze how they managed cognitive processes during problem-solving. This framework enabled the researcher to interpret not only students' geometric understanding but also their metacognitive awareness, problem-solving strategies, and capacity to plan, monitor, and evaluate their thinking. By linking these aspects, the analysis provided a deeper insight into how students approach complex geometry problems and how their cognitive and metacognitive skills interact to influence their learning outcomes.(Anderson & Dexter, 2020)

To measure students' ability in recognizing and interpreting visual information, several indicators of visual observation were developed. These indicators aim to identify how well students can perceive, analyze, and make sense of visual elements presented in learning materials. In addition, the indicators function as a framework for evaluating students' capacity to connect visual cues with underlying geometric concepts, such as relationships between shapes, spatial orientation, and symbolic representations. They also provide a reference for assessing the depth and accuracy of students' understanding when engaging with spatial and diagrammatic information. The detailed descriptions of these indicators are presented in Table 1.

Table 1. Visual Observation Indikator

No	Visual Observation Indicators	Code
1	Students are able to determine all the flat shapes contained in the image.	V1
2	Students are able to interpret the positional relationships between flat shapes.	V2
3	Students are able to interpret the symbols contained in the question.	V3
4	Students are able to interpret the meaning of the symbols displayed.	V4

Source: Indicators for assessing students' visual observation skills when interpreting geometric diagrams.Adapted from (Pólya, 1973; Sumarmo, 2010)

As presented in Table 1, the visual observation indicators encompass students' abilities to identify geometric figures, interpret spatial relationships, and comprehend the meaning of presented symbols. These indicators are essential for promoting higher-order thinking skills, as they require not only perceptual accuracy but also the ability to connect visual cues with underlying geometric concepts. In this way, they foster students' capacity to reason logically, recognize patterns, and draw meaningful conclusions from visual information. Consequently, assessing students based on these indicators provides deeper insights into their development of visual reasoning abilities and the extent to which they can translate visual representations into coherent mathematical understanding.

The coding process focused on identifying students' visual observation indicators and metacognitive regulation errors to analyze how they managed and controlled their cognitive processes during problem-solving activities. This analytical framework allowed the researcher to capture not only the students' understanding of geometric concepts but also the underlying mechanisms of their metacognitive awareness. Specifically, the analysis examined how students planned their approaches, monitored their progress, and evaluated the effectiveness of their strategies while solving geometry problems.(Salmela-Aro et al., 2022) By integrating these cognitive and metacognitive dimensions, the study provided a comprehensive picture of how students engage with complex geometry tasks. It revealed patterns in how visual information was perceived, interpreted, and transformed into problem-solving strategies. Furthermore, the framework highlighted the dynamic interaction between visual reasoning and metacognitive control showing that students who demonstrated stronger awareness of their thinking processes were more capable of adjusting their strategies when faced with challenges. Thus, this approach not only deepened the understanding of students' geometry learning processes but also underscored the importance of fostering both visual observation and metacognitive regulation to improve overall mathematical performance.(Sary et al., 2023). The identification of metacognitive regulation errors was essential to understand the students' reasoning process when solving geometry problems. Through this process, the researcher could pinpoint not only what types of mistakes were made, but also at which specific stage of thinking planning, monitoring, or evaluating these errors occurred. This categorization provides deeper insight into how students organize their strategies, track their progress, and judge the accuracy of their solutions. It also helps reveal patterns showing where their metacognitive control tends to weaken or break down, offering valuable information for targeted instructional support. The indicators of metacognitive regulation errors used in this study are presented in Table 2 below.

Table 2. Metacognitive Regulation Error Indicators

No	Metacognitive Regulation	Error Indicators	Kode
1	Planning	Students are unable to identify important information from the question.	P1
		Students do not determine an appropriate solution strategy.	P2
		Students choose the wrong formula or concept relevant to the question	P3
2	Monitoring	Students are unable to manage the solution steps correctly	M1
		Students do not check the suitability of the steps taken with the correct mathematical concept	M2
3	Evaluating	Students do not review the results obtained.	E1
		Students do not compare the results obtained with simple logic	E2
		Students do not find errors even though there are inaccuracies in the final results	E3

Source: Indicators for identifying students' metacognitive regulation errors during the planning, monitoring, and evaluation stages. (Pólya, 1973; Sumarmo, 2010)

The metacognitive regulation error indicators described in Table 2 serve as a reference in analyzing students' errors during the problem-solving process. Each code represents a specific type of error occurring at one of the three stages of metacognitive regulationplanning, monitoring, and evaluating. By categorizing students' errors based on these indicators, the researcher could systematically identify where and how students experienced difficulties in managing their thinking. The next section presents the results and discussion based on the analysis of students' responses and interview data.

RESULT AND DISCUSSION

The results of the geometry tasks showed clear variations in students' responses, which reflected differences in both visual observation and metacognitive regulation. To ensure the validity of these findings, follow-up interviews were conducted to explore students' reasoning processes in greater depth. The written responses and interview excerpts were analyzed together to illustrate each student's characteristic patterns of visual interpretation and cognitive regulation.

The findings can be understood within the framework of metacognitive regulation theory. As described by (Salmela-Aro et al., 2022), effective problem solving depends on three core components: planning, monitoring, and evaluating. Students who demonstrated stronger regulation across these phases were more successful in identifying geometric relationships, interpreting spatial structures, and selecting appropriate solution strategies. In contrast, students who struggled during the monitoring and evaluation stages tended to show fragmented reasoning, frequent misinterpretations of visual information, and procedural errors confirming earlier studies that associate weak metacognitive control with calculation mistakes and ineffective strategies (Wang et al., 2023).

From the perspective of visual observation theory, the findings reinforce the argument by (Pathuddin & Bennu, 2021) that perceptual accuracy is fundamental in geometry learning. Students with strong visual observation skills were able to identify component shapes, understand positional relationships, and integrate visual cues into coherent solution pathways. Conversely, students with low observation ability relied more heavily on memorized procedures rather than spatial reasoning, which limited their flexibility in solving unfamiliar or composite shapes.

Overall, these results contribute to a broader theoretical understanding of how cognitive and metacognitive processes interact in geometry learning (Uygun et al., 2024). The findings emphasize that visual reasoning and metacognitive regulation are interdependent: students who can accurately interpret visual information are better positioned to plan, monitor, and evaluate their solution steps. Therefore, effective geometry instruction should aim to strengthen both dimensions simultaneously—through targeted exercises, structured reflection, and problem-solving tasks that require students to justify their interpretations and decisions (Tarafdar et al., 2019).

First Subject (AO)

Subject AO is categorized as a high-ability student. AO's written work appears neat and systematic, and AO underlined key information in the problem. This behavior indicates early signs of visual observation as well as metacognitive planning, showing awareness of which information is essential for guiding the solution process.

In terms of visual observation, AO was able to identify most of the plane shapes presented in the figure. During the interview, AO stated: *"There is a square ABCD, triangle BCF, triangle BEF, triangle ECF, triangle AFD, and triangle CDF."* This response demonstrates AO's ability to recognize six geometric components accurately. However, AO failed to mention one shape right triangle CDE meaning AO did not fully meet indicator V1 (identifying all shapes), although the overall identification was still strong.

AO’s answer also reflected appropriate metacognitive regulation. The systematic presentation, the highlighting of important data, and the coherent reasoning steps indicate that AO engaged in planning, monitored the solution process effectively, and evaluated intermediate results before concluding. These behaviors align with metacognitive indicators P1- P2 and M1 - M2, showing that AO was able to manage the problem-solving process with minimal errors.

A figure of AO’s written solution is provided below to illustrate these observations.

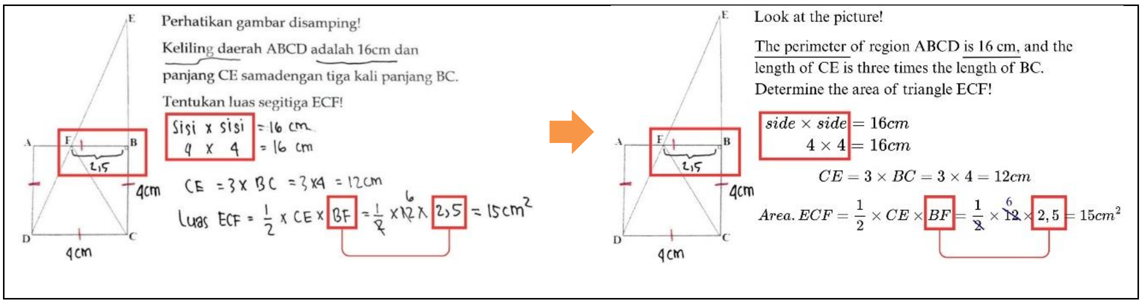


Figure 1. Student AO’s response showing strong planning and monitoring skills, but limited evaluation as indicated by the unverified height estimation.

Based on Figure 2, to find the solution for the area of triangle ECF, AO uses the information that the perimeter of square ABCD is 16 cm. Not only that, during the interview AO said “I know that the four lines indicate equal sides, so the shape is a square and there is also a right angle at B, its mean BF is the height of triangle ECF”. AO is able to explain signs and symbols well, so AO meets indicators (V3) and (V4).

Furthermore, AO shows planning to regulate his thinking when solving problems. When the researcher asked, “After you see the problem, what is the first thing you think of when reading the instructions?”, AO replied “I think find the length of the sides of the square first” This statement shows that AO is able to plan the initial step well. However, AO wrote “sisi x sisi = 16 cm” and AO also said “The formula for the perimeter of a square is side times side”. It can be seen that AO made a mistake in choosing the formula, because AO used the area formula. Although the final result of sides square ABCD 4 cm is correct, the thought process used is not entirely correct. AO was able to formulate an initial plan, but made a mistake in using the mathematical formula (P3).

AO was able to understand that CE is three times the length of BC by writing down that the length of BC is 12 cm. After that, AO wrote down a half times CE times BF to find the area of triangle ECF. This was confirmed by the statement “I used the formula half times the base times the height” CE is the base of the triangle, while BF is the height of the triangle. The error occurred when AO determined that the length of BF, or the height of the triangle, was 2.5 cm, based on his statement, “I estimate the length of BF to be 2.5 cm because F is located in the middle but slightly less. So, I just used that number for the height of the triangle” This indicates a discrepancy between the steps taken and the correct mathematical concept (M2)

After completing the calculation, AO checked the calculations and was sure there were no calculation errors. This was confirmed by the AO statement, "I am sure it is correct, because I checked all the steps and there were no calculation errors". This shows that there was no critical evaluation of the accuracy of the steps and the answers obtained, resulting in AO making errors (E1) and (E3).

AO was able to identify six flat shapes out of the seven flat shapes in the question, understand the symbols and signs correctly, and interpret the relationships between the flat shapes. Thus, AO met indicators (V2), (V3), and (V4). In terms of metacognitive regulation, AO made mistakes in choosing formulas (P3) and did not ensure that the steps were in accordance with the correct concept (M2), such as when estimating the height of a triangle. In addition, AO did not critically evaluate the results (E1, E3) because he was confident that the answers he wrote were correct. This is in line with the opinion of (Schraw, 1998) as the developer of metacognitive regulation theory, that individuals with high abilities more often ignore the evaluation process because they have high self-confidence. In general, AO with high mathematical ability has carried out all steps of metacognitive regulation. As shown in the results of (Pathuddin & Bennu, 2021) research, students with high ability tend to involve metacognitive regulation at every steps.

Second Subject (RSD)

Subject RSD represents the student with moderate mathematical ability. Unlike AO, RSD's written responses were less structured and did not include markings or underlining of key information from the problem. The absence of this step suggests that RSD did not fully engage in the planning stage (P1) of metacognitive regulation, which influenced how the student interpreted the given diagram.

In terms of visual observation, RSD identified only a portion of the geometric shapes. During the interview, RSD stated: *"There is a square ABCD, triangle BCF, and triangle ECF."* This response indicates that RSD recognized some shapes correctly but overlooked several others, leading to incomplete fulfillment of indicator V1 (identifying all shapes). RSD also struggled to interpret positional relationships among the shapes, showing a partial achievement of indicator V2.

Figure 2 displays RSD's written work. To determine the area of triangle ECF, RSD relied mainly on recalling formulas and procedural steps. However, RSD did not interpret the symbols or spatial cues effectively for example, failing to use the information about equal sides in square ABCD or the right-angle markers in the diagram. This limitation shows that indicators V3 and V4 were not fully met.

RSD's interview response, *"I just used the formula I remembered, so I thought it was correct,"* demonstrates weaknesses in monitoring (M1–M2) and evaluating (E1–E2). RSD performed calculations without checking intermediate steps or verifying whether the final result made sense.Overall, RSD's performance indicates moderate understanding but limited integration of visual information and metacognitive strategies, resulting in errors in both interpretation and computation.

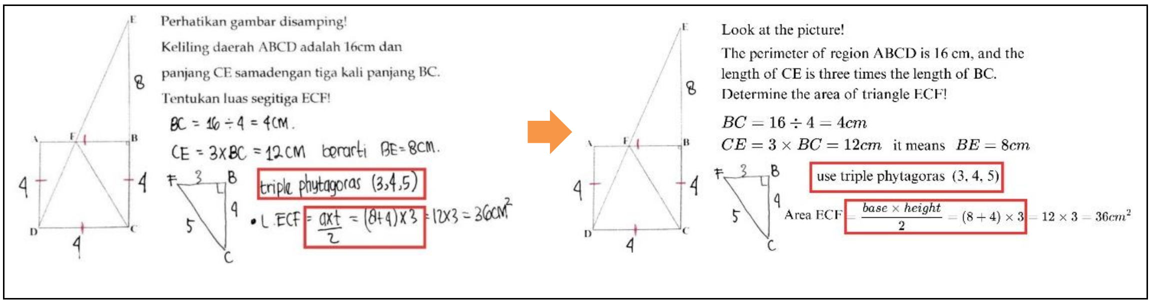


Figure 2. Student RSD's response reflecting partial visual observation and monitoring errors, including the misuse of the Pythagorean triple and lack of result validation.]

Based on Figure 3, RSD was able to determine that the lengths of BC, CD, and DA were each 4 cm. The calculation was written clearly, with BC obtained by dividing 16 by 4. This step was confirmed by RSD's statement: *"The perimeter is divided by four because the sides are the same length."* RSD applied the correct procedure and made no mistakes in calculating the sides of square ABCD. Furthermore, RSD accurately computed the lengths of CE and BE.

However, RSD made an error when determining the length of BF. The student directly applied the Pythagorean triple without verifying whether it was applicable, even though such a conclusion cannot be made when only one side is known. This indicates a conceptual misunderstanding (M2). In addition, RSD made an error in using the area formula for a triangle, omitting the division by two and instead multiplying the base by the height directly, representing another mathematical error (M1).

After completing the calculations, RSD mentioned: *"I double-checked to make sure there were no errors in the calculations."* Although this shows an effort to review the process, it also reveals that RSD's evaluation was procedural rather than critical—focusing only on arithmetic accuracy without questioning the logical reasonableness of the result. This lack of critical reflection led to evaluation errors (E1) and (E3). The resulting area calculated by RSD was 36 cm², which is disproportionately large. Considering that triangle ECF visually appears smaller than square ABCD, such a result should have prompted doubt about its plausibility. The absence of this reflective check suggests a metacognitive regulation error (M2), as RSD failed to assess the reasonableness of the outcome based on visual estimation.

Overall, RSD exhibited moderate visual observation skills and a fairly systematic problem-solving approach. However, RSD did not identify all plane figures in the diagram (thus not fulfilling indicator V1), although the student successfully interpreted spatial relationships and understood symbols (indicators V2–V4). In terms of metacognitive regulation, RSD initially planned the correct steps but demonstrated a misconception regarding the Pythagorean triple in right-angled triangles (M2). This aligns with the findings of Taamneh et al. (2024), who reported that students often misapply the Pythagorean theorem, assuming that if one side of a triangle fits a known triple, the entire triangle must also conform to it. Additionally, RSD used the incorrect area formula for triangles (P3) and failed to evaluate the result logically or visually (E1–E3).

Third Subject (CAG)

The third subject (CAG) students with low mathematical abilities. Compared to the answers of the two previous students, CAG answer appears to be shorter. Circle or underline the question and then write down the numbers obtained. CAG can only see two flat shapes in the question, namely square ABCD and triangle ECF, indicating that there are five other flat shapes that have been missed. This is confirmed by CAG statement, "*In the question, there are only square ABCD and triangle ECF*" This shows that it does not meet indicator (V1). However, CAG was able to correctly explain the four lines and right-angled triangle symbols, so that CAG meets indicators (V3) and (V4). Furthermore, based on the statement "CE is the base while BF is the height of triangle ECF," it indicates that we can see the position between the elements contained in the question to help determine the area of ECF, so that CAG meets the indicator (V2). Figure below is the CAG answer.

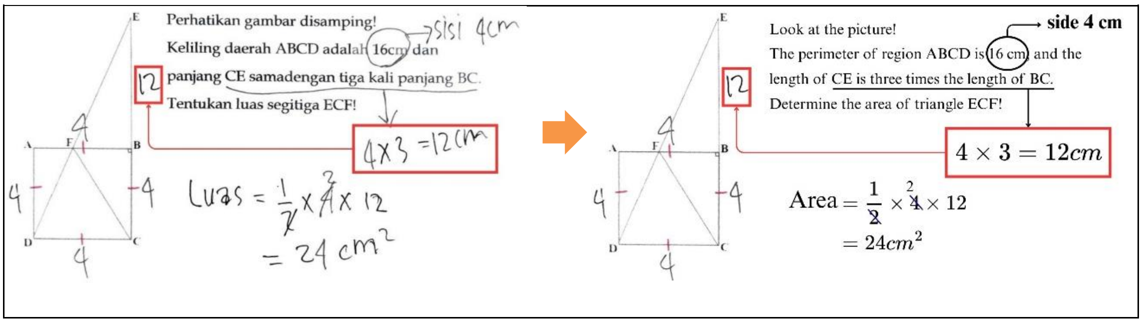


Figure 3. Student CAG's response demonstrating limited visual observation and multiple metacognitive regulation errors across planning, monitoring, and evaluating stages.

Based on Figure 4, RSD mark a circle with a radius of 16 cm and writes 4 cm on each side of ABCD, also writing it with the number 4. This was confirmed by the statement, "The sides of a square are all the same length, so the perimeter is divided by four to obtain the length of the side". Although not explicitly stated, CAG demonstrates great metacognitive regulation (planning) because uses and think the correct steps so that there are no errors when finding the length of the sides of square ABCD. Next, CE highlights the question and writes 4 x 3 = 12 cm, then sets its value as the length of BE. There is an error here, because 12 cm should be the length of CE, but it is set as the length of BE instead. Based on the CAG statement "The length of CE is the sum of the lengths of CB and BE. The length of CB already exists, which means that 12 cm belongs to BE". It indicates that CAG did not understand the question well (P1).

Next, to determine the area of triangle ECF, the subject wrote down as shown in Figure 4 and obtained a result of 24 cm². During the interview, RSD explained "I just divided 4 by 12, crossed out 2 and 4, then multiplied 2 by 12 to get 24 square centimeters" and the reason for using this method was "I remember the formula for the area of a triangle is half the base times the height" reiterating that "the base means the bottom and the height means the top" This indicates that CAG has a conceptual error regarding the area of a triangle. It can be seen that CAG did not determine the appropriate solution strategy (P2) and made a mistake in using the correct triangle formula (P3). Looking at the process used, it appears that CAG was unable to manage the solution steps correctly (M1). CAG also did not check the suitability of the steps taken with the correct mathematical concepts (M2). CAG stated that it had double-checked and was confident in its solution to the problem and the answer it had arrived at. However, CAG did not notice or find any errors in the final answer (E3). Like RSD, CAG also did not compare the area obtained with simple logic (E2).

Based on the results of the work and interviews, CAG showed many limitations in visual observation and metacognitive regulation errors. CAG was only able to name two flat shapes, thus failing to meet (V1), even though they were able to identify the base and height of a triangle (V2) and the meaning of symbols or signs in the questions (V3) and (V4). CAG metacognitive regulation was flawed at almost all stages: failure to identify important information (P1), failure to determine an appropriate strategy (P2), incorrect selection of formulas (P3), failure to manage steps correctly (M1), and failure to check consistency with concepts (M2). At the evaluation stage, CAG did not realize the mistakes made (E3) and did not compare the results with simple logic (E2). These findings are in line with the research by (Fu & Qi, 2025a), which found that students with low mathematical ability showed a variety of metacognitive regulation errors. Additionally, (Farsani & Oates, 2023) found that students with low mathematical ability exhibit limited visual observation.

CONCLUSION

Based on the results of this study involving three subjects with different levels of mathematical ability, it can be concluded that students with high mathematical ability demonstrated superior visual observation skills compared to those with moderate and low ability. The geometry problem consisted of seven interconnected flat shapes. Students with high ability successfully identified six shapes, those with moderate ability identified three, and those with low ability recognized only two. Interestingly, none of the subjects identified the right-angled triangle ECD, which was essential for solving the problem, indicating that all subjects failed to meet indicator (V1). However, all subjects met indicators (V3) and (V4), showing an understanding of symbols and spatial relationships.

In terms of metacognitive regulation, students with high mathematical ability engaged effectively in the planning and monitoring stages, although some errors occurred during planning and they tended to overlook the evaluation stage. Students with moderate ability made errors in monitoring and evaluating, while those with low ability struggled across all stages of metacognitive regulation. Overall, none of the subjects performed a thorough evaluation process, which contributed to the persistence of errors.

These findings suggest that mathematics educators should place greater emphasis on developing students' visual observation and metacognitive skills as part of geometry learning (Fu & Qi, 2025). Teachers can design structured visual exploration activities, such as guided diagram analysis or shape decomposition tasks, to help students better identify spatial relationships. In addition, integrating metacognitive trainingfor example, by prompting students to plan, monitor, and evaluate their reasoning explicitly during problem-solvingmay enhance their ability to self-regulate and reflect critically on their solutions.

For future research, it is recommended to expand the sample size and include students from different schools or grade levels to increase the generalizability of the findings. Comparative studies across educational contexts or curricula could also provide deeper insights into how metacognitive and visual observation skills develop under various instructional approaches. Furthermore, intervention-based studies could explore how targeted teaching strategies improve students’ cognitive and metacognitive performance in geometry.

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