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Analogical Reasoning Profiles of Prospective Elementary Teachers in Triangle and Quadrilateral Problems

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Abstract: Analogical reasoning allows prospective primary school teachers to connect familiar mathematical ideas with unfamiliar problems, yet recognising a resemblance does not always lead to a sound solution. This study explores how prospective primary school teachers establish and use mathematical relationships when solving an analogy task involving triangles and quadrilaterals. Using an exploratory qualitative design, the study examined written responses from 41 participants and conducted in-depth interviews with five selected participants, one from each response profile. The analysis considered four interrelated processes: encoding, inferring, mapping, and applying. Written responses were classified as advanced (2), explicit (12), implicit (7), incomplete (8), and non-analogy (12). The interview cases revealed distinct difficulties in identifying a relevant relationship, transferring it from the source to the target, and completing the calculation. Notably, one participant explored two different relationships, while another identified a plausible relationship but made an arithmetic error. These findings show that successful analogical reasoning involves more than obtaining the correct answer. Preparing future primary school teachers to explain, compare, and verify mathematical relationships may strengthen their understanding of geometry and their capacity to support children's mathematical thinking.

Keywords: Analogical Reasoning; Prospective Primary School Teachers; Geometry; Mathematical Reasoning; Problem Solving

Introduction

Mathematical analogies are useful when a familiar problem helps learners make sense of a new one. Yet noticing similar shapes is not enough: students must identify which mathematical relationship in the source problem can also be used in the target. In geometry, where one diagram may contain several overlapping triangles and quadrilaterals, choosing the relevant relationship can be more demanding than carrying out the calculation itself (Dumas et al., 2016; Vendetti et al., 2015).

Studies of analogical reasoning have examined how learners activate prior knowledge, identify corresponding structures, and encounter difficulties when transferring relationships between problems (Kristayulita et al., 2018; Sidney & Alibali, 2015). Research on students' construction of analogies (Hicks, 2024) and prospective teachers' attempts to make geometry problems more accessible (Rosyidi et al., 2025) further suggests that a correct answer does not tell the whole story. The route to the answer matters, particularly when several interpretations of a diagram are possible.

This issue has particular significance for teacher education. Prospective elementary teachers need to do more than solve a problem correctly; they must be able to explain why one relationship is transferable while another is misleading. A student may identify the correct source relationship but use a different one in the target, or may preserve the relationship while making an arithmetic error. These are different difficulties and call for different forms of teaching support (Hatisaru & Richardson, 2026; Samková et al., 2025).

Against this background, the present study examines written solutions and interviews from prospective elementary teachers completing a geometry analogy task. It explores the variety of responses, how students moved between source and target problems, and what their unsuccessful or incomplete solutions reveal about the process of mathematical reasoning.

The study draws on response categories associated with Pronk (2014). Explicit responses communicate a coherent source–target relationship; implicit responses contain a plausible relationship that is not fully articulated or is accompanied by a local error; incomplete responses establish some of the source relationship but do not carry it through to the target; and non-analogy responses do not establish a usable correspondence. An additional advanced profile describes responses that explore more than one mathematically distinct relationship. These labels refer to the work produced on the task, not to enduring characteristics of the students.

Three questions guide the analysis: Which response patterns appeared in the geometry task? How did students identify, infer, transfer, and apply mathematical relationships? Where did the reasoning become difficult, even when part of a solution was mathematically appropriate?

Analogical reasoning is grounded in relationships rather than in resemblance alone. Two diagrams may look different yet share the same mathematical structure, or appear similar while requiring different operations (Holyoak, 2012; Vendetti et al., 2015). For example, an area value could represent a single triangle, a combination of triangles, or a fraction of a larger figure. Distinguishing these interpretations requires students to explain what is preserved from one problem to the next (Casakin & Goldschmidt, 2000; Holyoak et al., 2010; Juthe, 2005; Kotovsky & Gentner, 1996).

Helping students make such correspondences explicit has been a recurring concern in research on mathematics learning (Hicks, 2024; Sidney & Alibali, 2015). It is equally important for teachers who use analogies to introduce unfamiliar concepts. Previous studies have considered analogy in textbooks, geometry lessons, and algebraic problem solving (Akcay, 2016; Lailiyah et al., 2018; Magdas, 2015). The present task adds a closer look at what students actually do when several relationships in the same diagram appear plausible.

The distinction between an explicit and an advanced response is especially relevant here. Producing a lengthy solution is not the same as proposing two different analogies: the latter requires different mathematical relationships, not merely alternative expressions of one calculation. The classification therefore concerns the structure of the solutions rather than a judgment about intelligence or mathematical creativity, which would require different evidence (Hammer et al., 2018; Pronk, 2014; Sa'dijah et al., 2019).

To examine the solutions, the study uses four interrelated processes: encoding (identifying relevant information), inferring (proposing a relationship in the source), mapping (connecting that relationship to the target), and applying (using it to obtain a result) (Dumas et al., 2016). Students may return to an earlier process while working on another; the stages provide a way to interpret the evidence rather than a fixed sequence everyone must follow.

Method

The study used an exploratory qualitative design centered on one geometry analogy task. Written solutions from the participating students provided an overview of the responses, while interviews with selected students offered a closer account of how mathematical relationships were recognized and used. The analysis considered both the final answers and the explanations leading to them.

Participants were 41 third-semester students in an elementary teacher education program at Institut Agama Islam Negeri Tulungagung, the institution's name at the time of data collection. Their written responses were grouped into advanced (n = 2), explicit (n = 12), implicit (n = 7), incomplete (n = 8), and non-analogy (n = 12) profiles. Five students were then selected for in-depth interviews, one from each response profile. Thus, although two students were classified in the advanced profile, S1 represents the single advanced-profile case examined through an interview. Selection considered the characteristic features of the written response and the student's ability to explain the reasoning in conversation.

Participation was voluntary. The study describes a consent process that informed students of their right to decline participation or withdraw and of the confidential handling of their responses. Interview cases are presented under the pseudonyms S1–S5.

Students completed an analogy of the form A : B :: C : D. The source diagram (A) was paired with the value 6 (B), while the target diagram (C) required a corresponding value (D). Both diagrams contained triangular and quadrilateral regions. The task invited students to identify a relationship that explained the source value and consider how it could be used in the target (Figure 1).
Students were instructed to determine the value of D after considering the relationship between A and B.

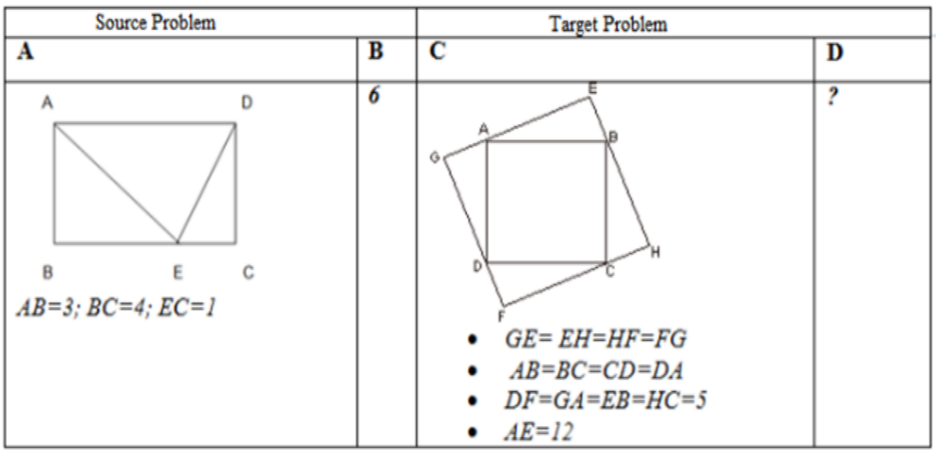


Figure 1. Source–Target Geometry Analogy Task

Several relationships can account for the value shown in the source diagram. Table 1 sets out the four relationships considered in the analysis; the numerical answer alone is not sufficient to show which one a student intended.

Table 1. Candidate Source–Target Relationships Used to Interpret the Task

Relationship	Source expression	Explanation of proposed mapping
R1	4.5 + 1.5 = 6	Sum the areas of the two right triangles in the source; apply the same sum-of-parts rule to the target.
R2	(4 × 3) ÷ 2 = 6	Take half the total outer area; apply half the target outer area.
R3	(4 × 3) ÷ 2 = 6	Select the largest triangular component of the source and a geometrically corresponding component in the target.
R4	12 − 6 = 6	Subtract a selected largest component from the total area; verify the selection and correspondence before coding.

The 41 written responses were initially described through the five response profiles. The written work of S1–S5 was then read alongside the interview excerpts, focusing on what information each student noticed, how a relationship was chosen, and whether it remained consistent in the target. The analysis follows the evidence in these five cases without assuming that all students within a profile reasoned in precisely the same way.

Written and spoken explanations were compared to identify where they supported one another and where steps were present only in the interview. The case descriptions retain the students' mathematical operations so that interpretations of each relationship remain visible to the reader.

Results

The 41 responses were described through five profiles: advanced (2), explicit (12), implicit (7), incomplete (8), and non-analogy (12). Together, they show a wide range of ways in which students approached the same geometric task. One student from each profile was interviewed, with S1 selected from the two advanced-profile students. The five cases (S1–S5) make the differences more concrete, particularly in the way a relationship was inferred from the source and carried into the target.

Exploring more than one mathematical relationship

S1 approached the problem by looking for more than one relationship between the source diagram and its given value. The first approach centered on the largest triangular region in the source and the corresponding internal region in the target. A second approach used half the area of the outer figure. The two attempts show how attention can shift between different parts of a diagram while the underlying analogy remains the central question.

S1 first examined the source triangles and calculated the area of triangle ADE as 6 (Figure 2). The student appeared to search for a region whose area matched the given value, rather than beginning with a predetermined formula.

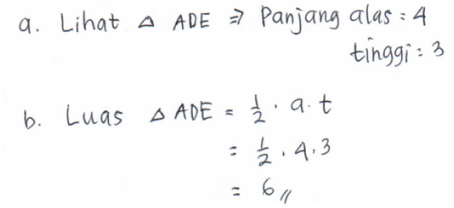


Figure 2. S1's Written Work: Initial Identification of a Region

For triangle ADE, the recorded base and height were 4 and 3, giving an area of ½ × 4 × 3 = 6. The interview offers a glimpse of this exploratory approach:

> *At first, I was confused on what I should fill in column D due to the shape of the structure, which is different with the one in target problem. I dabbled without writing to determine the area of each triangle in the source problem.*

Having identified the triangular region, S1 used its area to explain the source value of 6 (Figure 3). The next step was to find a corresponding region in the target, rather than simply repeat the original calculation.

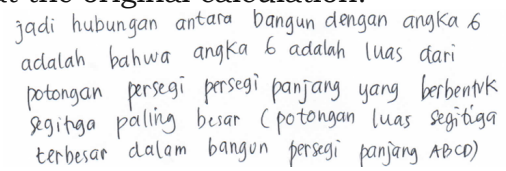


Figure 3. S1's Written Work: Establishing a Source Relation

S1 selected the inner quadrilateral ABCD in the target as the corresponding region (Figure 4). This move from one shape to another is central to the proposed analogy: the relationship concerned the chosen region, not the shared appearance of the diagrams.

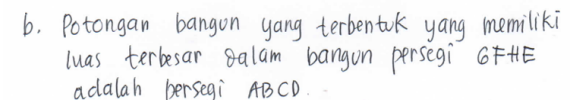


Figure 4. S1's Written Work: Mapping the Relation to the Target

Using a side length of 13, S1 then obtained an area of 169 for the inner square (Figure 5). The interview linked this calculation to the Pythagorean theorem:

> *"In order to calculate the length of AB, which was the side of the ABCD square using the Pythagorean Theorem, I calculated the value of ABCD area using the rectangle with formula A."*

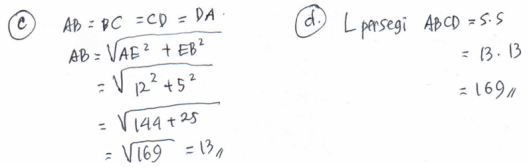


Figure 5. S1's Written Work: Application of the First Relation

The solution treats ABCD as a square with a side length of 13.
The area is therefore calculated as 13 × 13 = 169.
Reported area = 13 × 13 = 169.

After completing that solution, S1 returned to the task and considered another relationship. The student explained the decision in the interview:

> *"There was still available time, therefore, I tried to determine another solution. The existing images were visible, and I used another method to provide the necessary solution."*

In the second approach, the source value was taken as half the area of its outer rectangle: 12 ÷ 2 = 6. Applying this relation to the outer square of the target gives 289 ÷ 2 = 144.5 (Figure 6). The earlier written transcription presents this result as 144.6; the arithmetic expression itself gives 144.5. More importantly for the present analysis, S1 did not merely repeat the first solution but changed the relationship used to connect the two diagrams.

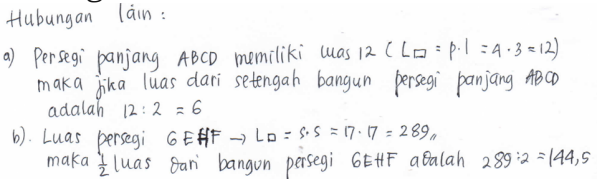


Figure 6. S1's Written Work: Second Proposed Source–Target Relation

The second approach uses half of the outer figure's area.

1. Source: 12 ÷ 2 = 6.
2. Target: 289 ÷ 2 = 144.5.

Carrying a relationship from the source to the target

S2 found a different way of explaining the same source value. Instead of focusing on the largest single region, S2 combined the areas of two right triangles. The relationship was then carried to the four corresponding triangles in the target, where it led to an answer of 120.

Not every step appeared on S2's written sheet. The student described recognizing the given side lengths without recording them in full: The interview indicates that S2 identified the relevant lengths mentally before making the calculations.

"What was known in the problem was the length of the sides of the rectangle. I did not write it in full because even without writing it down, I was able to answer the problem and people already understood what I meant."

S2 calculated the two source-triangle areas as 4.5 and 1.5, whose sum matched the given value of 6 (Figure 7). The interview suggests that the student moved between the source and target diagrams before settling on the sum-of-parts relationship. In this case, inferring and mapping were connected rather than strictly consecutive.

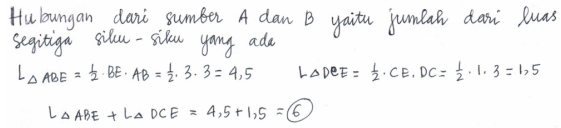


Figure 7. S2's Written Solution in the Inferring Process

The source value was interpreted as the combined area of two right triangles.

The written calculation shows the relationship explicitly:

A Δ DCE = ½ . CE. DC = ½ .1.3 = 1.5

A Δ ABE + A Δ DCE = 4.5+1.5 = 6

The search for the relationship was not immediate. S2 first considered individual triangles and then recognized that their areas could be combined. The student described that change of approach as follows:

"I needed a prolonged time to determine the relationship between A and B, and when I saw that there were right triangles in the source and target problems, I tried to obtain the area. The result did not fit to 6, therefore I tried to add them, which worked. Therefore, I found the relationship to the source problem, which was the value of 6 on B is the sum of the right triangles in A."

S2 applied the same sum-of-parts idea to the target. Four triangles, each calculated as having area 30, produced a total of 120 (Figure 8). In contrast with the alternative solutions proposed by S1, S2's written response followed one relationship through to a final answer.

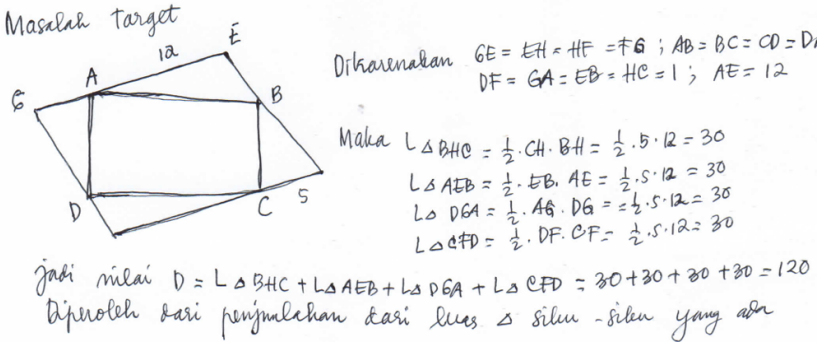


Figure 8. S2's Written Work: Application of the Triangle-Sum Relation

In the target, S2 identified four triangular regions and calculated their areas separately.

A Δ BHC = ½ . CH. BH = ½ .5.12 = 30

A Δ AEB = ½ . EB. AE = ½ .5.12 = 30

A Δ DEA = ½ . AE. DE = ½ .5.12 = 30
A Δ CFD = ½ . DF. CF = ½ .5.12 = 30
So D = A Δ BHC + A ΔAEB + A ΔDEA + A ΔCFD = 30 + 30 + 30 + 30 = 120

The contrast with S3 is instructive. S3 also recognized a relationship that could be carried across the diagrams, but the numerical work did not produce a consistent final answer. The student saw the source value of 6 as half the rectangle's area of 12, leading to 12 ÷ 2 = 6.

S3's initial identification of information is clearer in the interview than in the written answer. The student described rereading the problem and examining the given measurements before attempting a solution:

> *"When I read the problem, I was confused on what to determine. I reread the instructions and examples, checked what was known and observed the relationships that are likely to occur in order to determine an answer."*

S3 then wrote the half-area relationship in the source diagram (Figure 9). Unlike the incomplete cases discussed below, the difficulty did not begin with an inability to propose a mathematical correspondence.

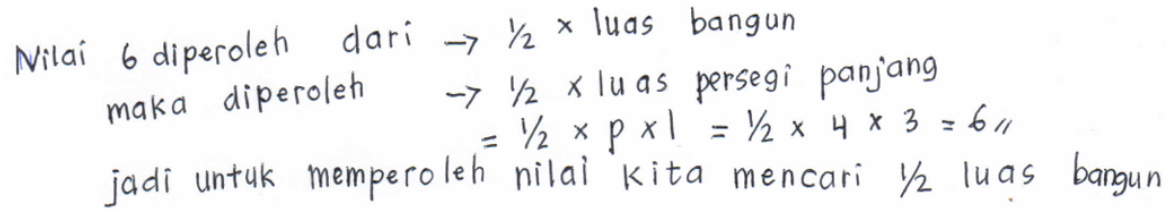


Figure 9. S3's Written Work: Identifying Half the Source Area

The source relationship is expressed as one-half of the rectangle's area.

½ × 4 × 3 = 6.

The same half-area operation was subsequently considered for the target.

For the target, S3 combined the area of the inner square with that of the four surrounding triangles before taking one-half of the total (Figure 10). The interview makes the intended relationship reasonably clear:

> *"The relationship that I found in the source problem is half of the area of the rectangle. Therefore, the target problem can be sought by determining the largest structure area and by adding four right triangles and ABCD rectangle."*

S3's written solution reveals an arithmetic error, although the underlying analogy was appropriate. The student identified the inner square as having an area of 169 and the four surrounding triangles as having a combined area of 120. The correct sum is 289, and half of this area is 144.5. In the original student response, however, 169 + 120 was incorrectly calculated as 189, leading to an answer of 94.5 (Figure 10). This is treated as an authentic feature of the student's work rather than corrected in the original evidence. It illustrates a distinction between identifying a valid source–target relationship and executing the associated calculations accurately.

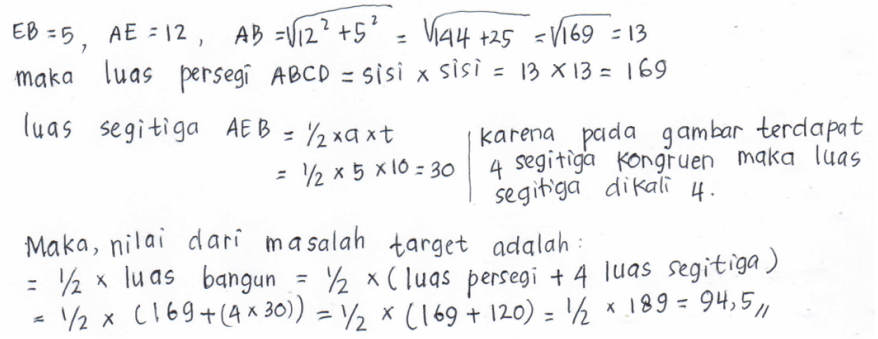


Figure 10. S3's Written Work: Applying the Half-Area Relation

The written calculation uses a square of side 13 and four right triangles with base 5 and height 12.

Area of the square: 13 × 13 = 169.
Area of each triangle: ½ × 5 × 12 = 30.
Combined area of four triangles: 4 × 30 = 120.
Using those values, the half-area relation gives:
½ × (169 + 120) = 144.5.
In S3's original answer, the incorrect intermediate sum led to ½ × 189 = 94.5.

Where a promising relationship did not lead to a solution

S4 encountered a different difficulty. The student identified a triangular region in the source with an area of 6 but did not preserve that choice when moving to the target. The result was an incomplete analogy: some useful source reasoning had been established, yet it did not lead to a corresponding target calculation.

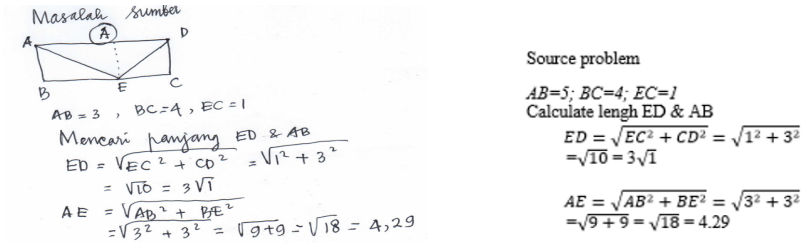


Figure 11. S4's Written Work: Identification of Given Information

S4 began by noting the given lengths in the source:

AB=5; BC=4; EC=1

The student then attempted to find additional lengths needed for area calculations. The target diagram was also considered through its given lengths and equalities:

EG=EH=HF=FG; AB=BC=CD=DA; DF=GA=EB=HC; AC=12

S4 calculated the areas of several source triangles, including triangle AED with an area of 6 (Figure 12). The calculation explained why this region attracted the student's attention, but identifying a plausible source region did not by itself resolve the analogy.

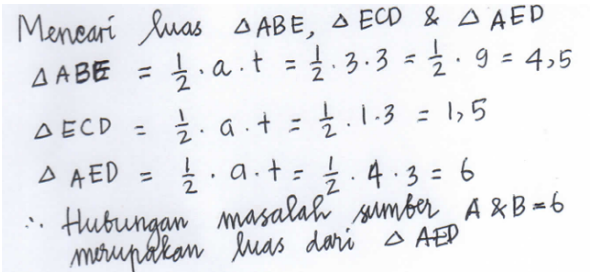


Figure 12. S4's Written Work: Comparing Source Triangle Areas

The source calculations distinguished three triangular regions:

A Δ ABE = ½ x b x h = ½ x 3 x 3 = 4.5
A Δ ECD = ½ x b x h = ½ x 1 x 3 = 1.5
A Δ AED = ½ x b x h = ½ x 4 x 3 = 6

S4 associated the source value with triangle ADE.

The interview confirmed that matching the given value of 6 was important to this choice:

"There were three triangles, and when I calculated the area of each the area of the AED triangle was 6."

The difficulty emerged in the target. S4 calculated the outer square's area as 17 × 17 = 289, although that region did not correspond to the triangle selected in the source (Figure 13). Thus, the individual area calculations were not necessarily the central obstacle; the relationship was lost during transfer.

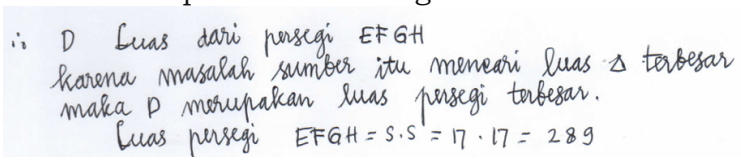


Figure 13. S4's Written Work: Unsuccessful Transfer to the Target

For the target, S4 used the outer-square area, 17 × 17 = 289.

S5's response was more limited. Although the student recorded several lengths from the source figure, these observations were not developed into a stable relationship that could also explain the target. The case was consequently described as non-analogy within this task (Figure 14).

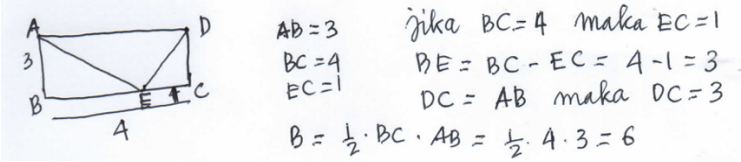


Figure 14. S5's Written Work: Identification without a Valid Mapping

In the source figure, S5 noted BC = 4, EC = 1, and therefore BE = 3.

The written work also included the expression ½ × 4 × 3 = 6, but did not develop it into a consistent target relationship.

The interview reinforced the uncertainty visible in the response. When asked about the solution, S5 explained:

"I did not know what to look for, therefore, I wrote down anything that crossed my mind on my answer sheet."

Viewed together, the five cases suggest that the most consequential differences arose not from the number of calculations students performed, but from how they established and maintained mathematical correspondences. Table 2 brings these differences together by summarizing the five written and interview records.

Table 2. Reasoning Evidence from Five Interviewed Cases

Response profile	Evidence from the written work and interviews
Advanced (S1)	S1 explored two source–target relationships: the area of a selected inner region (169) and half the outer figure's area (144.5).
Explicit (S2)	S2 added the areas of two source triangles (4.5 + 1.5 = 6), carried this relation to four target triangles, and obtained 120.
Implicit (S3)	S3 recognised the half-area relation, but the recorded calculation moved from 169 + 120 to 189 and finally 94.5.
Incomplete (S4)	S4 identified a source triangular region of area 6, then used a noncorresponding outer region in the target.
Non-analogy (S5)	S5 identified some lengths but did not develop them into a usable source–target relationship.

Discussion

The findings bring attention to a distinction that is easy to miss when judging mathematical work from the final answer alone. Identifying a quantity, finding a mathematical relationship, carrying that relationship to a new configuration, and computing the final value are connected activities, but they do not always succeed together. S3, for example, proposed a workable half-area relation while the reported computation became inconsistent. S4 recognized a source region yet selected a different kind of region in the target. Both cases highlight the importance of examining students' explanations, not simply marking their final numbers as right or wrong (Shodikin et al., 2021; Subanji & Nusantara, 2016; Utami et al., 2019).

S1's two approaches also have implications for how response profiles are interpreted. The advanced label is useful only when the approaches represent genuinely different relationships, rather than two ways of writing the same operation. In the present task, S1 considered a selected inner region and then half the outer figure's area, whereas S2 pursued one coherent sum-of-parts relation. This comparison suggests that the ability to justify an alternative mapping may be worth examining in future research, without treating one task response as evidence of a fixed level of cognitive ability (Pronk, 2014).

The interviews further suggest that reasoning did not always follow a neat sequence. S2 reconsidered the source while looking at the target, moving between candidate relationships until a workable correspondence emerged. Such movement fits a process-oriented understanding of analogical reasoning (Dumas et al., 2016). It also reflects the value of discussing the mathematical structure of a problem, rather than teaching students to follow a sequence of steps without examining why those steps apply (Hicks, 2024; Rosyidi et al., 2025).

The distinction between a useful analogy and a correct computation is equally important. S3's half-area relationship could be explained, yet the numerical record included an inconsistent intermediate total. In instruction, students therefore need opportunities to justify the correspondence and to check whether the arithmetic faithfully represents it. These are complementary practices: one concerns the conceptual relationship, and the other concerns the accuracy of its application.

S4 and S5 point to different forms of support. For S4, a prompt to mark corresponding regions in both diagrams may have helped preserve the chosen source relationship. For S5, the more immediate need was to identify and explain a source relationship before considering the target. Similar attention to the stages of mathematical analogising has appeared in studies of younger learners (Agusantia & Nurlaelah, 2023), although this study's university participants and single task do not permit direct comparisons across age groups.

For prospective teachers, these distinctions have a practical consequence. A classroom analogy should make a mathematical idea more intelligible, not merely produce a familiar-looking diagram. Asking future teachers to explain what is shared, what changes, and why the relationship remains valid may help them choose and teach analogies more carefully (Hatisaru & Richardson, 2026; Samková et al., 2025). Research connecting analogical reasoning with mathematics learning among children lends further relevance to this concern, while involving populations different from the present sample (Qi et al., 2024; Stevenson & Bergwerff, 2013).

The study should nevertheless be read within its limits. It examines responses to one constructed analogy and interviews one participant from each profile; the findings cannot establish how stable those profiles would be across mathematical topics. The available written and interview excerpts also do not determine the origin of every numerical discrepancy. Research with several tasks, repeated interviews, and explicitly documented classification decisions would help show whether these response patterns recur.

Conclusion

The findings suggest that successful analogical reasoning in geometry depends not simply on recognising similarities between figures, but on understanding and transferring the mathematical relationships underlying them. The five reasoning profiles reveal differences in how prospective primary school teachers identify relevant information, establish connections, and apply mathematical ideas to unfamiliar problems. While some participants demonstrated flexibility in exploring alternative relationships, others encountered difficulties in maintaining appropriate correspondences or completing mathematical calculations accurately. These differences highlight the importance of examining students' reasoning processes rather than relying solely on the correctness of their final answers. For primary teacher education, the findings underscore the value of learning experiences that encourage prospective teachers to explain mathematical relationships, consider alternative solutions, and critically evaluate their reasoning. Although the study was limited to one geometry task and five in-depth interviews, it offers a useful perspective on how analogical reasoning can be understood and supported during teacher preparation. Further research across different mathematical contexts may provide a deeper understanding of these processes and their implications for elementary mathematics teaching.

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Author Contributions

Musrikah contributed to the conceptualisation and design of the study, development of research instruments, data collection, analysis and interpretation of findings, and manuscript preparation. The author also reviewed and approved the final version of the manuscript.

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Declaration of AI Usage

The author used ChatGPT to assist with language editing, academic writing refinement, and manuscript preparation. All research data, analyses, and

interpretations were reviewed by the author, who takes full responsibility for the accuracy, originality, and integrity of the manuscript.

Conflict of Interest

The author declares no financial, personal, or professional conflicts of interest that could have influenced the conduct or reporting of this study.

Data Availability

The data supporting the findings of this study, including anonymised written responses and interview materials, are maintained by the author and may be made available upon reasonable request, subject to participant confidentiality and ethical considerations.

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