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The Characteristics of Analogical Reasoning of Senior High School Students in Solving Geometry Problems

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Abstract

When students solve two geometry problems with almost the same concept, students try to interpret and understand the information and the problem. Because students can choose the plans or steps to tackle the problem, this step is crucial. When thinking about the relationship between things and their integration, analog reasoning is required. This study attempts to describe the characteristics of different types of analogical reasoning that 10th-grade students use while solving geometry problems based on the phases of analogy. In this descriptive qualitative study design, to solve geometry issues, twenty-four students had to work their way from the source problem to the target problem. Three types of analogical reasoning were identified: misleading, incomplete, and structural analogy. Each type reflects different levels of understanding and reasoning stages in solving geometry problems. First, the misleading analogy type, in which students perform inaccurate geometry interpretation and important information in the problem is not considered; second, incomplete analogy, in which students provide appropriate geometry representation, but there are still errors in understanding part of the problem; third, structural analogy type, in which students perform geometry representation with comprehensive conceptual understanding. Therefore, teachers should encourage students to build a deeper understanding and find meaningful conceptual connections through the conceptualization of geometry.

Keywords: *Characteristics, Problems Geometry, Reasoning Analogy*

Karakteristik Penalaran Analogi Siswa SMA dalam Menyelesaikan Masalah Geometri

Abstrak

Ketika siswa menyelesaikan dua masalah geometri dengan konsep yang hampir sama, siswa mencoba menginterpretasikan dan memahami informasi dan masalah tersebut. Langkah ini sangat penting, karena siswa dapat menentukan langkah atau rencana untuk menyelesaikan masalah tersebut. Penalaran analogi diperlukan dalam mempertimbangkan hubungan antar objek dan keterpaduannya. Tujuan penelitian ini adalah mendeskripsikan karakteristik beberapa jenis penalaran analogi yang digunakan oleh siswa-siswi kelas 10 dalam menyelesaikan masalah geometri berdasarkan tahapan analogi. Penelitian ini menggunakan jenis deskriptif kualitatif dengan melibatkan dua puluh empat siswa yang diminta untuk menyelesaikan masalah geometri dari masalah sumber ke masalah target. Hasil penelitian

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menunjukkan bahwa penyelesaian siswa dapat dikelompokkan menjadi tiga jenis penalaran analogi. Dari setiap kelompok, satu siswa diwawancarai untuk mendapatkan lebih banyak data tentang tipe-tipe ini. Pertama, tipe analogi menyesatkan, dimana siswa melakukan iterpretasi geometri yang tidak tepat dan informasi penting dalam soal tidak dipertimbangkan; kedua, analogi tidak lengkap, dimana siswa memberikan representasi geometri yang tepat, namun masih terdapat kesalahan dalam memahami bagian dari soal; ketiga, tipe analogi struktural, dimana siswa melakukan representasi geometri dengan pemahaman konseptual yang komprehensif. Oleh karena itu, guru harus mendorong siswa untuk membangun pemahaman yang lebih dalam dan menemukan hubungan konseptual yang bermakna melalui konseptualisasi geometri.

Kata kunci: *Karakteristik, Masalah Geometri, Penalaran Analogi*

INTRODUCTION

Problem-solving ability is one part of high-level thinking skills (HOTS), which are very useful for students in facing life's challenges and are relevant to 21st-century skills. The results of the study show that when the class starts with an open problem, it will provide space for students to solve, and create their problems and problem-solving strategies (Intaros et al., 2014). However, in reality from observations, students have difficulty in problem-solving activities which are thought to be confused with drawing conclusions from the facts in the problem (Hidayah et al., 2020). Problem-solving does not only rely on mechanical procedures but depends on students' ability to build logical arguments and look for patterns, which is often known as the reasoning process. There are many types of reasoning that students can apply, one of which is analogical reasoning. Analogy helps students to build a deeper understanding of concepts, not just procedural (English, 1993). In learning, analogical reasoning is needed to conjecture a concept that will run systematically and logically (Herawati & Akbar, 2019).

Analogy is a statement of a relationship in which one term is similar to another term (King, 1886). Analogy is a kind of similarity, analogous objects or things have similarities in certain aspects through analogous relationships of their component parts (Magdaş, 2015). In language, analogy is comparing two objects, or systems of objects by highlighting things that are considered similar. Analogical reasoning is a process of logical thinking that uses analogy as a tool to draw conclusions (Herawati & Akbar, 2019). Analogical reasoning relies on comparisons between two systems that can have the same or similar domains or different domains but are considered similar in some

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way. Analogical reasoning plays an important role in problem-solving (English, 1993). However, problem-solving with an analogical reasoning approach shows differences in students' schemas. Kristayulita (2021) found differences in students' analogical reasoning scheme models. The first type of student can directly map the target problem to the source problem. In the second type, students cannot directly map between the target problem and the source problem, but students need to represent the target problem so that they find a problem form that has similarities with the source problem. Learning techniques that demand problem-solving from students strongly promote the development of students' reasoning. Research shows that students who use the Problem-solving learning model with the Scientific Approach experience a significant increase in adaptive reasoning (Andika & Pramudya, 2020). This time the author shows learning innovation through an analogical reasoning approach to solving problems, especially geometry. The study (Dhlamini et al., 2019) showed that on average 70.5 percent of the total number of students remembered and combined previous knowledge that was irrelevant and inappropriate to the context of geometry problems. The author believes that the analogical reasoning approach will demand students the skills of remembering, combining, and manipulating problems in context.

Kristayulita, et al., (2020) stated that the stages of solving source and target problems with an analogy reasoning approach include: students must first (1) identify the target problem and search for similarities between it and the source problem, (2) map the target problem's characteristics to the source problem one at a time, (3) solve the target problem using the source problem-solving process, and (4) compare the results of the target problem with the source problem. As opposed to problem-solving by indirect analogy. Kristayulita (2021) shows that in solving and solving indirect analogy problems there are components of representation and mathematical modeling, structuring, mapping, applying, and verifying. In solving indirect analogy problems, there are additional stages of analogical reasoning at the beginning, namely representation (Hodiyanto & Juniati, 2022). After obtaining scaffolding, both male and female students had finished the four parts of the analogical reasoning process: encoding, inferring, mapping, and applying. It was discovered that male students' analogical reasoning had nearly reached the mapping stage prior to receiving scaffolding, but that the mapping stage was still lacking. This indicates that there are

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differences in cognitive strategies between men and women in mathematical reasoning, especially analogy reasoning. (Azizah et al., 2021) demonstrates that students with a systematic cognitive style can comprehend the problem by thoroughly mentioning all of the information they are aware of and asking to apply it in a planned, structured manner, whereas students with an intuitive cognitive style can only comprehend the problem by reading it once and mentioning the information they are aware of in order to apply it in a planned, but unstructured, way. The results found that students have different beliefs about the nature and process of proof, and use and understand analogical reasoning in unique ways (Bayaga et al., 2021). Learners can be taught ways to use analogies in order to improve skills in reading comprehension and making inferences in various fields (King, 1886). Analogical reasoning approach was also conducted on open-ended question types. The findings demonstrated that students' analogical reasoning in addressing real-world problems with both open-ended target problems and closed-ended source problems fell into three categories, specifically: (1) full open analogy, (2) full semi-open analogy, and (3) closed open analogy failure (Rochman & Amir, 2023). Thus, analogical reasoning serves as an important tool to accelerate the understanding of abstract geometry concepts and supports the development of more flexible and adaptive problem-solving abilities.

This study provides insight into the characteristics of students' analogical reasoning in solving geometry problems as well as providing recommendations for teachers in improving more meaningful geometry learning. Classifying students' analogical reasoning skills in solving geometry problems is the study's suggested remedy. This study uses one analogical problem that has similarities between the source problem and the target problem and was developed by the researcher so that it is different from the analogy problem used by previous researchers. (Kristayulita, et al., 2020) employed two analog issues: (1) analogy problems that were similar between the source and target problems, and (2) analogy problems that were distinct between the source and target problems. Researchers will describe the characteristics of students' analogical reasoning in solving geometry problems based on their stages that are comprehensively researched through interviews. Data reduction refers to the process of selecting, simplifying, abstracting, and transforming data that appears in field notes or transcripts (Lailiyah et al., 2022). The researcher raised the following problem: "How

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are the characteristics of students' analogical reasoning in solving geometry problems?". The purpose of the study is to describe the characteristics of students' analogical reasoning in solving geometry problems, by paying attention to the stages of analogy involved as well as factors that affect the effectiveness of analogy.

RESEARCH METHODS

This study uses a descriptive qualitative methodology to fully characterize the aspects of students' analogical reasoning when solving geometry problems. In order to incorporate philosophical understanding in addition to theoretical information, qualitative research is a methodology that focuses on studying phenomena that are unrelated to the study of causes and effects that have already been described or that define some distribution (Şen et al., 2023). Descriptive qualitative research is research to understand and describe a phenomenon in a natural situation in depth by utilizing qualitative methods (Ferdiani et al., 2021). The research subjects involved 24 students of SMA 15 Surabaya grade 10 in Surabaya Regency, East Java, Indonesia working on analog problems in the context of geometry. All subjects had received flat-building learning at the previous level. After the written test results were obtained, students' answers were grouped based on the characteristics and structure of the solution, and then selected research subjects representing each group were to be interviewed regarding the solutions on the answer sheet. With commonalities between the source and target problems, the written test instrument takes the form of a single analog problem. Although the problem's solution involves algebra, it is related to the idea of geometry. Analog problems can be seen in Table 1.

Table 1. *Problems Related to Geometry*

Source Issue	Target Issue
Find 4 congruent circles that intersect each other at points A, B, C, and D. Determine the ratio of the area enclosed by the 4 circles to the sum of the areas of the 4 circles that intersect ABCD.	Find 3 congruent circles that are tangent to each other at points A, B, and C respectively. Find the ratio of the area enclosed by the 3 circles to the sum of the areas of the 3 circles that intersect ABC.

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RESULTS AND DISCUSSION

This study has obtained three types of analogical reasoning that are reviewed at the stage of analogy in solving geometry problems, namely Misleading Analogy type, Incomplete Analogy type, and Structural Analogy type. Three types were identified based on the work of 24 students in solving geometry problems. The first group contained 14 students, consisting of students who could not understand all the information as well as errors in interpreting the source problem and target problem. They have different perceptions related to what the problem wants. Meanwhile, these perceptions were not structurally or conceptually relevant. As a result, the analogies used were misleading and resulted in misunderstanding in the solution. The second group contained 7 students, consisting of students who were able to interpret the geometry of the source problem and target problem correctly. However, they lacked understanding of what was asked in the problem. As a result, the answers that appeared were not in accordance with what was asked, but the concepts and solution strategies applied were in line with the expected strategies for the problem. The third group has 3 students, consisting of students who can understand all the information and interpretations geometrically appropriate to the source problem and target problem. Other studies also show differences in the answers of each student. From the data obtained, it was identified that the processes involved in logic skills showed some differences (Suprapto et al., 2023). Overall, in the answers, students have applied the analogical reasoning approach. To find out in more detail how students' reasoning, the following are the results of interviews with the three subjects, namely subject 1 (S1), subject 2 (S2), and subject 3 (S3).

Analogy Reasoning in Problem Solving Process S1

Subject 1 started the solution by illustrating the 4 circles intersecting horizontally. With this assumption, S1 directly interpreted that what was questioned in the problem was the ratio between the sum of the areas of the 4 circles and their squares.

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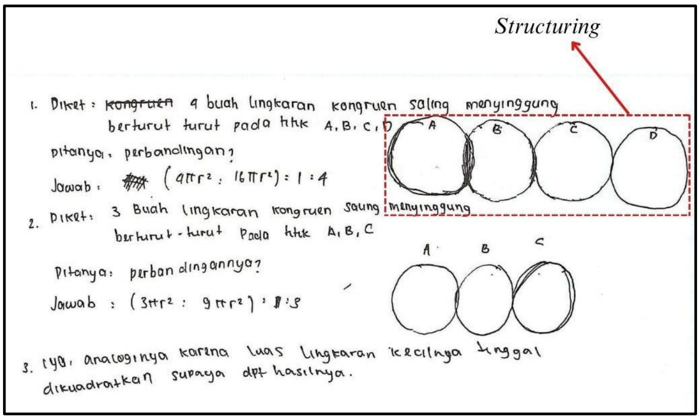

Figure 1. *S1 Subject's work*

The subject cannot understand the questions raised by the source and target difficulties, as shown in Figure 1. There was a disparity in the answers because the solution approach for the source problem was developed without a solid grasp of geometry. However, the analog reasoning approach was applied in solving the target problem even though it just repeated the process without adding any new concepts. This can be seen in the following interview.

R : *"How do you understand the first problem?"*

S1 : *"I arranged the 4 circles horizontally with tangent points A, B, C, D respectively. In the problem, it is known that there are 4 circles, so I calculated the total area and compared it with the square area. From that situation, I got the ratio 1: 4."*

R : *"Why did you compare the total area with the square?"*

S1 : *"Because it is known that there are 4 circles and I slightly remember the concept of circle so I immediately did the strategy."*

From the interview, S1 solved the second problem with the same strategy and method as the first problem. This is shown in the following dialogue.

R : *"Is there any similarity in solving the first problem with the second problem?"*

S1 : *"There is, both are looking for a comparison of the area in question and the solution strategy are the same, so it is easy to answer the second problem."*

R : *"Is there no fundamental difference in the strategy or concept of the two*

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problems?"

S1 : "No, only the comparison result is different, and the number of points of tangency."

R : "Are you sure about your answer?"

S1 : "A little less sure because I haven't mastered the concept of a circle"

R : "Try to look at the question again"

S1 : "(Thinking for a moment), Oh yes, yes, this is wrong because the command is to find the area of the area enclosed by the 4 circles."

From the results of the interview, S1 at the beginning of the work was not sure of his answer because the final result and the problem question did not match. In terms of the stages of analogy, subject 1 had difficulty in understanding geometric shapes and relationships between elements so it only reached the structuring stage. This shows that the subject was unable to apply the stages of analogy appropriately. S1 was categorized as a student with limited mathematical representation skills because his failure to comprehend the first problem prevented him from solving the target problem using the stages of analogical reasoning. According to Utami et al., (2019) research, most students still struggle with mathematical representation, which makes it hard for them to comprehend and write equations from the supplied issues.

Analogy Reasoning in Problem Solving Process S2

The stages of analogical reasoning carried out by subject S2 are a level better than the stages of analogy by S1, especially the prominent difference in the visualization of the first and second problems in geometry. This can be seen in the results of S2's work shown in Figure 2.

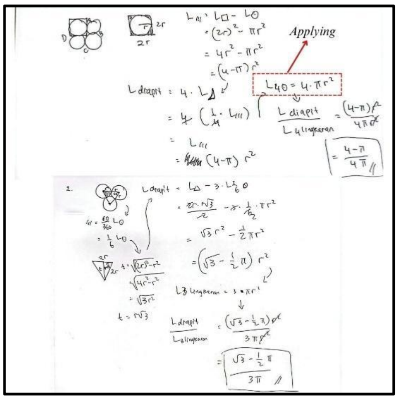

Figure 2. *S2 Subject's work*

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Based on Figure 2, the geometric illustrations in the first and second problems are in accordance with the information given so that the calculation of the area of the enclosed area is correct and even the strategy used is quite creative. However, there is an interpretation error in calculating the total area of the circle intersection with the flat shape formed by the tangent point of the circle. In finding the area of the enclosed area, S2 used the Pythagorean Theorem formula on special triangles. This is shown in the following dialogue.

R : *"How did you get the area of the apex area in the first problem?"*

S1 : *"I arranged the 4 circles according to the picture. Then I made a square that holds a circle. From there I calculated the area of the square minus the area of the circle in it algebraically."*

R : *"Then from the calculation of the enclosing area you compared it with the area of the whole circle, then how did you get the area shaded in the second problem?"*

S1 : *"Yes. I calculated the area of the enclosing area in the second problem using almost the same strategy as the first problem. However, I calculated from the triangle formed by the centre point then I subtracted with ½ the area of the circle."*

R : *"Why did you reduce the area of the triangle by ½ the area of the circle?"*

S1 : *"Because the magnitude of each angle of the triangle is 60 degrees and if the total is 180 degrees, then this is equal to ½ the area of the circle."*

R : *"Are you sure about your answer?"*

S1 : *"Sure."*

From this dialogue, S2 understood some of what was questioned in the problem. However, through this understanding, S2 was able to form a mathematical model in his answer based on facts and logical statements. The use of the solution strategy in the second problem is not much different from the first problem, except that there is a fundamental difference, namely the addition of the concept of the Pythagorean theorem and the area of the jurying is related to the size of the central angle of each circle. In

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terms of the stages of analogy, S2 is in the Applying phase, meaning that it does not fulfill all four stages of analogy so there is an error in the final result. The calculation of the area of the intersecting circles in the second problem shows a different answer concept, where S2's answer is the total area of the three circles. The results of this analysis are in line with the found that there are still errors in solving problems related to geometry made by students, the results of the study (Elsa et al., 2022) showed conceptual errors caused by a lack of understanding of the concept and the selection of formulas that are less precise in solving geometry problems of space buildings.

Analogy Reasoning in Problem Solving Process S3

S3 can solve the first and second problems very precisely. His answer shows that they are able to illustrate geometrically and understand what is asked. The results of S3's work can be seen in Figure 3.

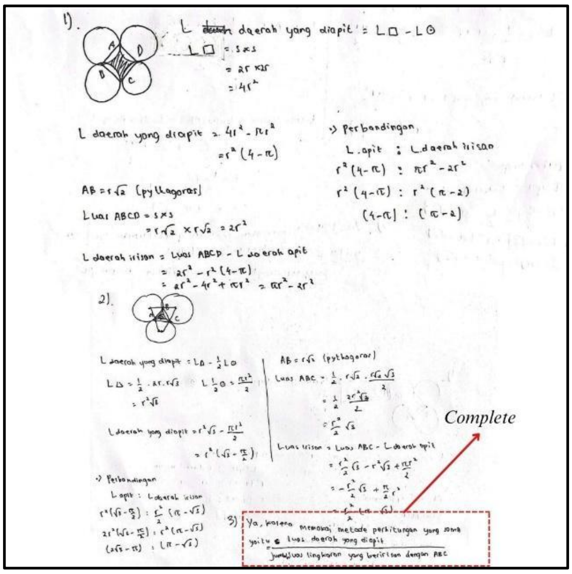

Figure 1. S3 Subject's work

Based on Figure 3, S3 solved the second problem through the strategy obtained in the first problem by adding some new concepts such as the Pythagorean theorem and the total area of the bucket. So it is not entirely the strategy obtained in the first problem applied to the second problem so S3 shows that the strategy applied fulfills all stages of analogy ranging from structuring, mapping, and applying to verifying. S3 can be classified as a student who has above-average mathematical ability. According to research (Aini et al., 2020) (Dokuz Eylul University & Canturk Gunhan, 2014), Higher levels of creative thinking are displayed by visual-spatial pupils, indicating that they are

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better at learning mathematics, especially when it comes to geometry-related material.

Data analysis in this study described three types of analogical reasoning based on students' mathematical ability level, namely misleading type, incomplete type, and structural type. An explanation of the characteristics of each type is shown in Table 2.

Table 2. Characteristics of Students in Analogy Reasoning

Type of Analogy Reasoning Based on Stages	**Description of Characteristic**
Misleading Analogy	• The visual representation did not show the geometric structure referred to in the problem. • There were misconceptions about the problem statement in both the source and target contexts. • The solution strategy was based on surface similarity, not structural similarity. • The analogy stage stopped at the structuring stage, without continuing for mapping, applying, or verifying. • The final solution is not relevant to the problem in question.
Incomplete Analogy	• Geometry representation was appropriate, but there were still errors in understanding some of the problems. • The analogy mapping process was carried out but not fully conceptually accurate. • The stages of analogy reached structuring, mapping, and applying, but did not include verifying. • The final result contained conceptual errors due to inaccuracy in verifying the solution.
Structural Analogy	• Visual and geometry representations demonstrate comprehensive conceptual understanding. • The mapping process between source and target problems is based on structural relations and relevant geometry principles. • The solution strategies were adaptive, with the integration of new concepts such as buckets and the Pythagorean theorem. • All stages of analogy were met: structuring, mapping, applying, and verifying. • The final solution is mathematically correct, demonstrating mature and reflective analogical thinking skills.

Based on the analysis findings in Table 2 above, the three subjects, the three types of analogical reasoning in solving geometry problems, have the following specific characteristics: students fail to consider important information in the problem from the

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source problem to the target problem, and the misleading type of analogy is a wrong interpretation of geometry. Qualitative evidence of student work shows that errors in visualizing the geometry of the story problem tend to hinder determining the required formula (Agustin & Sa'dijah, 2024). The other two types of analogy reasoning, incomplete analogy, and structural analogy, both start with a complete geometric interpretation of the problem presented. However, students with the incomplete type chose to connect or compare with inappropriate concepts so that the comparison results did not match the actual compared context.

Meanwhile, the structural type can understand the problem through the stages of analogy so that the answer is in accordance with the concept being asked. These two types certainly have a higher success rate than the first type of misleading analogy. The fundamental difference between the incomplete and structural types lies in the quality of the verification process carried out by students. In the incomplete type, students stop after applying the strategy without evaluating whether the solution obtained has answered the question correctly. Many students do not actively use their metacognitive skills in solving mathematics problems, especially in the evaluation and verification stages (Nisa Rambe & Sinaga Asmin, 2019). This shows that students do not have good metacognitive skills in verifying their work. (Suliani et al., 2024) highlighted that students who have low metacognitive awareness tend not to realize the conflict between existing mental models and new concepts learned through analogy. Meanwhile, the structural type shows a process of reflection on the fit between the solution and the question, as well as the integration of additional concepts in a logical and relevant manner, such as the use of the Pythagorean theorem and the area of the bucket. This process indicates higher order thinking skills and mature mathematical representation abilities. In line with Sridana et al., (2025) research, students with high-level thinking skills are able to use various representations, such as verbal, symbolic, and visual, effectively in solving mathematical problems. In the analogical reasoning scheme, the three types lead to different processes, but incomplete and structural are not too contradictory. This is consistent with the analogy reasoning scheme model in students as described by Kristayulita (2021), in which the first category of students is able to directly map the source problem to the target problem prior to the stages of organizing, implementing, and confirming. Although they cannot directly connect the two problems,

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students in the second kind must portray the target problem in order to find a problem form that is comparable to the source problem.

Thus, understanding these types of analogy reasoning is important for teachers in identifying the form of pedagogical intervention needed. Students with misleading analogy types need guidance in constructing appropriate visual representations and linking problem information with basic geometry concepts. This method can be achieved by providing scaffolding and guided discovery to students (Frederick et al., 2014) Shodikin et al., 2021; Ön Hallumoğlu et al., 2023). While students with incomplete analogy type need training in verifying solutions and increasing their metacognitive awareness. As for students with structural types, they can be given further challenges to develop their creative and reflective thinking skills further. It is necessary to provide further challenges to students with structural analogy type to further develop their creative and reflective thinking skills (Shoimah et al., 2018).

CONCLUSION

The sorts of analogical reasoning that students used to solve geometry problems pertaining to its stages were collected by the study. The findings revealed several categories, including structural, incomplete, and deceptive analogies. Both structural and incomplete analogy types are highly useful in the process of addressing problems. Therefore, teachers need to encourage students to use creative thinking strategies and observe similarities and geometric visualizations of mathematical problems. Analog reasoning with structural analogy type can encourage students to build a deeper understanding and find meaningful conceptual connections. By recognizing the characteristics of each type of analogical reasoning in solving geometry problems, teachers can design appropriate pedagogical interventions, both to correct errors in representation mapping and to encourage the exploration of more reflective and creative solution strategies. This research on analogical reasoning was conducted on grade 10 students who had just interacted with the environment and materials at the high school level. Students in grade 12 can provide somewhat different results. Thus, it is advised that future studies look at grade 11 pupils' analogical reasoning.

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