p-ISSN: 2086-4280
e-ISSN: 2527-8827

Junior High School Students' Analogical Reasoning in Geometry: A Preliminary Study for Learning Model Development

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Article received: 20-08-2025, revision: 17-09-2025, published: 30-10-2025

Abstrak
Studi pendahuluan ini bertujuan untuk menganalisis penalaran analogi siswa SMP pada materi bangun ruang sisi datar sebagai dasar untuk mengembangkan model pembelajaran matematika yang lebih efektif. Penalaran analogi memiliki peran penting dalam mendukung berpikir matematis tingkat tinggi dan pemahaman konseptual, namun kemampuan siswa di bidang ini masih tergolong rendah. Penelitian deskriptif kualitatif ini melibatkan tiga siswa kelas IX dari 3 SMPN yang berada di Kota Tasikmalaya. Subjek dipilih secara purposive yaitu masing-masing satu orang siswa dari 3 sekolah yang memiliki nilai rata-rata matematika tertinggi. Pengumpulan data dilakukan melalui tes penalaran analogi, wawancara semi terstruktur, dan dokumentasi dengan fokus pada empat komponen utama penalaran analogi yaitu encoding, inferring, mapping, dan applying. Hasil penelitian menunjukkan bahwa penalaran analogi siswa secara umum masih tergolong rendah, terutama pada komponen inferring, mapping dan applying. Temuan ini mengindikasikan bahwa kesulitan siswa tidak hanya bersumber pada lemahnya penguasaan konsep, melainkan juga akibat minimnya strategi pembelajaran berbasis analogi yang eksplisit dan sistematis di kelas sehingga diperlukan pengembangan model pembelajaran yang efektif untuk mengembangkan penalaralan analogi.
***Kata Kunci**: Geometri; Pembelajaran Matematika; Penalaran Analogi; Siswa SMP.*

Abstract
This preliminary study aims to analyze junior high school students' analogical reasoning on the material of flat-sided solid shapes as a basis for developing a more effective mathematics learning model. Analogous reasoning has an important role in supporting high-level mathematical thinking and conceptual understanding, but students' abilities in this area are still relatively low. This qualitative descriptive research, involving three ninth-grade students from three junior high schools in Tasikmalaya City. The subjects were selected purposively, namely one student each from 3 schools who had the highest average mathematics score. Data collection was carried out through analogical reasoning tests, semi-structured interviews, and documentation with a focus on the four main components of analogical reasoning, namely encoding, inferring, mapping, and applying. The results show that students' analogical reasoning is generally still relatively low, especially in the inferring, mapping and applying components. This finding indicates that students' difficulties do not only stem from weak conceptual mastery, but also from the lack of explicit and systematic analogy-based learning strategies in the classroom, so that it is necessary to develop effective learning models to develop analogical reasoning.
Keywords: Geometry; Mathematics Learning; Analogical Reasoning; Junior High School Students.

I. Introduction

Mathematics learning plays a crucial role in developing students' logical, critical, and systematic thinking skills. (Decree of the Head of BSKAP Number 008/KR/2022) states that one of the mathematics learning objectives set by the Indonesian government in the independent curriculum is for students to use reasoning on patterns and properties, perform mathematical manipulations to make generalizations, construct evidence, or explain mathematical ideas and statements (mathematical reasoning and proof) (Agusantia & Juandi, 2022). According to the National Council of Teachers of Mathematics, one of the main objectives of mathematics learning is to develop reasoning skills as a basis for understanding concepts and solving problems (NCTM, 2000; Pradiarti & Subanji, 2022; Maulandani & Afriansyah, 2024).

Students' reasoning skills are a crucial component in the mathematics learning process. According to Ridhoi et al. (Ridhoi et al., 2020), mathematical reasoning plays a role in developing logical, analytical, and critical thinking, thus influencing how students understand and process mathematical concepts. One essential form of reasoning in mathematics learning is analogical reasoning, the ability to connect existing knowledge to new situations or concepts through similar relationships or structures (Gentner & Smith, 2012; Ardiansyah & Wahyuningrum, 2022).

Field evidence shows that mathematics learning in junior high schools, particularly on flat-sided geometric shapes, still tends to be procedural and oriented towards memorizing formulas. This is in line with the findings of Susilawati et al., (2025), who stated that students experience difficulties in applying knowledge to new situations because learning still emphasizes memorization. Learning that emphasizes procedures without conceptual understanding can hinder the development of student reasoning. As a result, students experience difficulties in understanding the relationships between geometric elements, distinguishing the characteristics of various shapes, and applying concepts in different contexts. This condition indicates that students' analogical reasoning abilities have not developed optimally.

The importance of analogical reasoning in mathematics learning is supported by constructivism theory. According to Piaget (Piaget, 1969), the learning process occurs when students actively construct new knowledge based on existing cognitive structures. Furthermore, Gentner (1983) Structure Mapping Theory explains that analogical reasoning involves mapping the corresponding relationships between source and target domains. In mathematics learning, this process helps students understand abstract concepts by linking them to more familiar concepts.

Analogy is a type of similarity. Similar objects or things exist in certain aspects, analogous objects or things according to certain analogous relationships of their components (Polya, 2004; Yani, Haryono, & Lovia, 2022). Furthermore, Richland and Simms (2015) stated that analogy is a reasoning process that starts from two or more specific events that have similarities to each other. In analogical reasoning, the main focus lies in finding similarities or similarities between two different objects

p-ISSN: 2086-4280
e-ISSN: 2527-8827

or situations, then these similarities are used as a basis for drawing a conclusion. Analogous reasoning is a conclusion with similar properties and structure of the relationship of the source problem to be applied to the target problem (Ridhoi et al., 2020). According to Aichelburg et al., (2016) analogical reasoning is defined as a form of relational reasoning, because similarities concern the relationships between elements of a situation or object rather than the elements themselves. Analogical reasoning is the cognitive foundation of the ability to notice and draw similarities across various contexts. The 4 components of analogical reasoning proposed by Stenberg (1977) in English (2009), are: (1) Encoding, (2) Inferring, (3) Mapping, and (4) Applying.

English (2004) (revealed that many students have difficulty in identifying relational similarities and transferring analogies to new problems. In addition, Vendetti et al., (Vendetti et al., 2015) showed that the explicit use of analogies in learning can improve students' conceptual understanding, but its effectiveness is highly dependent on students' initial readiness and analogical reasoning abilities. Leonard et al., (Leonard et al., 2023) stated that although verbal analogical reasoning tasks are similar to analogies in everyday life, students find it difficult to translate them into something testable in a comparative context because they depend not only on language but also on some fundamental conceptual knowledge in the real world.

Analogical reasoning is an important topic to study because it plays a significant role in students' success in understanding and solving mathematical problems. However, research conducted by Vebrian et al. (2025) shows that students' mastery of mathematical reasoning skills is relatively low. One factor contributing to this low mathematical reasoning ability is students' lack of understanding of basic mathematical concepts. Angraini et al. (Angraini et al., 2023) demonstrated that the analogical reasoning abilities of junior high school students in Indonesia are still diverse and are strongly influenced by prior knowledge and the character of the material, with students' success rates higher in arithmetic than in more abstract geometry. Analogical reasoning requires not only the recognition of similarities but also the ability to flexibly switch from one representation to another, which is strongly influenced by cognitive control mechanisms in the brain (Valle et al., 2020; Sofiani, Nurjamil, & Nurhayati, 2023).

Research conducted by Ridhoi et al. (Ridhoi et al., 2020) revealed that students' analogical reasoning in geometry material is still generally classified as low. Research by Fatimah & Imami (2021) concluded that students' analogical reasoning has not yet reached the Minimum Completion Criteria (KKM), thus remaining in the low category. Research by Nurhalimah & Haerudin (2021) showed that students' analogical reasoning is in the moderate category. Research conducted by Nurhalimah & Haerudin (2021) showed that reasoning ability in the analogical reasoning indicator is classified as low. Furthermore, Agusantia & Juandi (2022) in their research using the SLR method suggested that research on students' analogical reasoning can be optimally developed, it is necessary to conduct in-depth analysis and identify causal factors both in the learning process and in problem-solving.

One of the mathematics materials at the junior high school level that demands high reasoning skills is the material on flat-sided solid figures. This material involves various abstract concepts, such as the relationships between solid elements, nets of solid figures, and calculations of surface area and volume, which often cause difficulties for students. In line with the importance of analogical reasoning skills, initial studies that analyze students' analogical reasoning in depth as a basis for developing learning models are still limited, especially on the material on flat-sided solid figures at the junior high school level. According to Plummer & Krajcik (2010), understanding students' thinking methods is a crucial step before designing effective learning interventions. Therefore, analyzing students' analogical reasoning is a strategic initial solution in developing learning models and designing more effective learning strategies, especially those oriented towards strengthening analogical reasoning, so that learning can take place more meaningfully.

II. Method

This study uses a descriptive qualitative method with the aim of in-depth description of junior high school students' analogical reasoning on the material of flat-sided solid shapes as a basis for developing an effective learning model. The study was conducted at 3 junior high schools in Tasikmalaya City. The research subjects were grade IX students who were selected using purposive techniques. From each school, one student was selected who had the highest average mathematics score with the aim of obtaining a more in-depth picture of thinking skills, problem-solving strategies, and optimal understanding of mathematical concepts. Students with the highest scores are assumed to have mastered the material better and are therefore able to solve the problems given.

The research material focused on the material of flat-sided solid shapes, with questions designed to measure students' analogical reasoning. The main research instrument was the researcher herself and used a supporting instrument in the form of an analogical reasoning test in the form of a description developed based on three indicators of analogical reasoning: similarity of processes within one topic, similarity of processes between topics, and similarity of processes in the context of everyday life. In addition, it also paid attention to the four components of analogical reasoning: encoding, inferring, mapping, and applying. Another instrument used was a semi-structured interview guide to explore students' thinking processes in more depth. Instrument validation was carried out through expert judgment by two mathematics education lecturers. Research data were obtained through a semi-structured interview analogical reasoning test, and documentation was then analyzed based on the analysis of Miles and Huberman (1984) in Sugiyono (2020) which consists of data reduction, data display, and conclusion drawing/verification.

III. RESULT AND DISCUSSION

The results of this study were obtained from the analysis of analogical reasoning test data, semi-structured interviews, and documentation of junior high school students on the topic of flat-sided solid figures. The researcher is denoted by Q, students from school 1 are denoted by S1, students from school 2 are denoted by S2, and students from school 3 are denoted by S3. The research results were obtained from the results of the analogical reasoning test based on the analogical reasoning question indicators.

A. Analogous Reasoning in Question Number 1, an Indicator of Similarity of Processes in One Topic

Mastery of prerequisite skills or understanding of the basic concepts of flat solid figures is an important stage in developing analogical ability in the topic of solid figures. Through this analogical process, students can solve problems of solid figures by utilizing concepts learned in previous materials. Based on the data analysis obtained, subjects with high analogical reasoning abilities are illustrated by the following results.

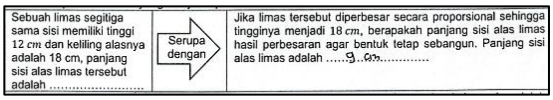

Figure 1. S1's Answer to Question Number 1.

Q : *What concept was used to answer the problem in column 1?*

S1 : *Using the circumference concept with the formula k = 3s*

Q : *What were the results?*

S1 : *I don't know, miss*

Q : *How did you connect the concept in the problem in column 1 with the problem in column 3?*

S1 : *Using similarity, miss*

Q : *How did you use the concept from the previous problem to solve this problem?*

S1 : *Using the proportionality formula, miss*

Q : *What were the results?*

S1 : *9 cm*

Q : *Where did you get that value?*

S1 : *Just estimate, miss. I forgot because I missed the material.*

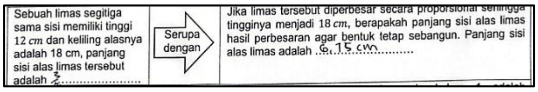

Figure 2. S2's Answer to Question Number 1.

Q : *What concept was used to answer the problem in column 1?*

S2 : *Using the new base side.*

Q : *What was the result?*

S2 : *3 cm*

Q : *How did you connect the concept in the problem in column 1 to the problem in column 3?*

S2 : *Using the magnification scale =* $\frac{10}{12} = \frac{3}{2}$.

Q : *How did you use the concept from the previous problem to solve this problem?*

S2 : *Magnification scale*

Q : *What was the result?*

S2 : *The length of the new base side is 6.75 cm.*

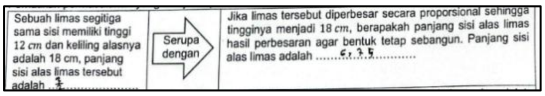

Figure 3. S3's Answer to Question Number 1.

Q : *What concept was used to answer the problem in column 1?*

S3 : *Using the new base side.*

Q : *What was the result?*

S3 : *3 cm, miss.*

Q : *How did you connect the concept in the problem in column 1 to the problem in column 3?*

S3 : *Using the magnification scale, miss.*

Q : *How did you use the concept from the previous problem to solve this* *problem?*

S3 : *I don't know, ma'am. I just estimated it, because I forgot the previous material and never covered it.*

Q : *What was the result?*

S3 : *The length of the side is 6.75 cm.*

B. Analogous reasoning in question number 2, an indicator of the similarity of processes between topics

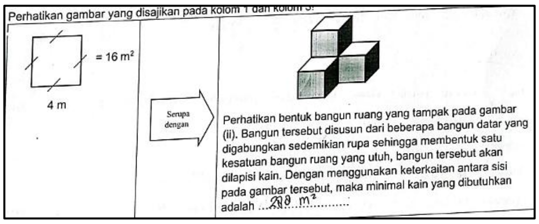

Figure 4. S1's Answer to Question Number 2.

Q : *What concept do you use to answer the problem in column 1?*

S1 : *Use the formula for the area of a square, miss, which is s x s.*

Q : *How do you connect the concept in the problem in column 1 to the problem in column 3?*

S1 : *Use the concept of area.*

Q : *How do you use the concept from the previous problem to solve this problem?*

S1 : *Use the formula for surface area, miss.*

Q : *What is the result?*

S1 : *The result is* $288\ m^2$

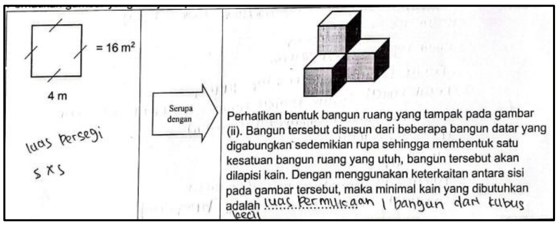

Figure 5. S2's Answer to Question Number 2.

Q : *What concept was used to answer the problem in column 1?*

S2 : *Using the formula A = s x s.*

Q : *How did you connect the concept in the problem in column 1 to the problem in column 3?*

S2 : *Using the concept of the area of a plane figure.*

Q : *How did you use the concept from the previous problem to solve this problem?*

S2 : *The number of visible sides of the cube.*

Q : *What was the result?*

S2 : *A spatial figure, miss.*

Q : *Yes, I mean, what is the area?*

S2 : *I forgot how to do it again, miss.*

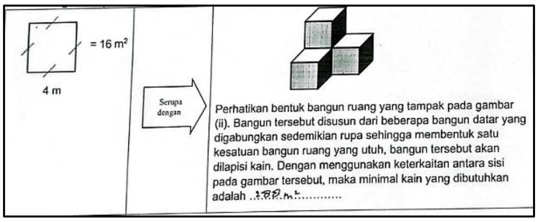

Figure 6. S3's Answer to Question Number 2.

Q : *What concept is used to answer the problem in column 1?*

S3 : *Using the formula L = s x s.*

Q : *How do you connect the concept in the problem in column 1 to the problem in column 3?*

S3 : *Using the area of a plane figure, miss.*

Q : *How do you use the concept from the previous problem to solve this problem?*

S3 : $L = s^2$.

Q : *What is the result?*

S3 : *The result is* $288\ cm^2$.

Q : *Where did you get that result?*

S3 : *From the visible side, miss.*

C. Analogous reasoning in question number 3, an indicator of the similarity of processes in the context of everyday life.

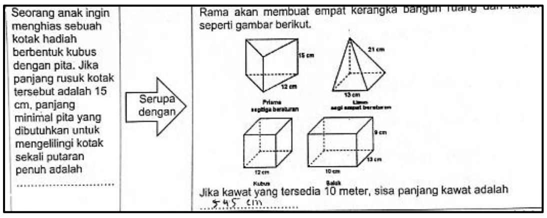

Figure 7. S1's Answer to Question Number 3.

Q : *What concept was used to answer the problem in column 1?*

S1 : *Using the circumference or edge length, miss.*

Q : *What was the result?*

S1 : 180 cm.
Q : How did you connect the concept in the problem in column 1 to the problem in column 3?
S1 : Finding the perimeter.
Q : How was it calculated?
S1 : The formula for a cube is 12 x s, 4(l + w + h).
Q What was the result?
S1 545 cm.

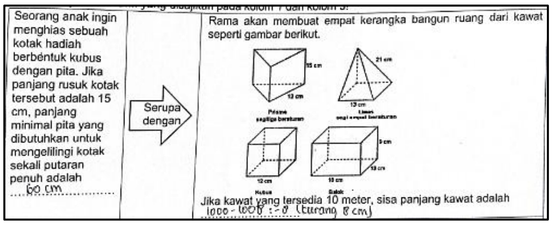

Figure 8. S2's Answer to Question Number 3.

Q : What concept was used to answer the problem in column 1?
S2 : Using the length of the wire and the number of edges.
Q : What was the result?
S2 : 60 cm
Q : How do you connect the concept in the problem in column 1 with the problem in column 3?
S2 : cube + pyramid = 252 cm.
Q : What concept was used?
S2 : frame method: 1000-1008 cm
Q : What was the result?
S2 : 8 cm short.

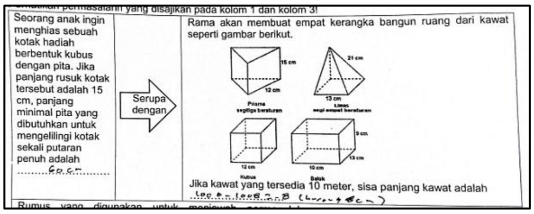

Figure 9. S3's Answer to Question Number 3.

Q : What concept was used to answer the problem in column 1?
S3 : I don't know, miss.
Q : What was the result?
S3 : 60cm
Q : Where did you get that result?
S3 : There are 4 squares, so multiplying them by 15 makes 60.
Q : How did you connect the concept in the problem in column 1 with the problem in column 3?
S3 : Maybe using a cube.
Q : How did you use the concept from the previous problem to solve this problem?
S3 : I don't know, I forgot, miss
Q What was the result?
S3 I'm confused, ma'am, because the material hasn't been covered before.

During the activity, the author also asked several supplementary questions that were not directly related to the main activity given to the students. These included:

Q : Of all the subjects, do you like mathematics?
S1 : I quite like mathematics, but it depends on the material. If the material is understandable and involves lots of practice, I find it enjoyable.
S2 : I like it, miss, but I don't like it when it's connected to previous material, as in the previous question.
S3 : I like counting, miss, rather than subjects that require a lot of memorizations, but don't use previously learned material, because I often forget it again.
Q : Do you find it easier to understand the material on geometric shapes during the lesson if it's accompanied by pictures or models rather than just explanations of formulas? Why?
S1 : Yes, it's easier with pictures because I can immediately see the shape and visualize the dimensions. However, when the lesson is only about formulas, I often get confused about where the formulas come from.
S2 : I think pictures are very helpful, especially for differentiating similar shapes. With just formulas, I often confuse one shape with another.
S3 : I think I would understand better if there were examples of pictures or

real objects, because I could relate them to objects, I have seen.

Q : *Does the lesson often connect new material to previously learned material?*

S1 : *Not very often. Usually, teachers immediately explain new material without connecting it to previous lessons.*

S2 : *Rarely. Even if they do, it's only briefly mentioned and not discussed further.*

S3 : *I don't think it's often, because each topic feels like a new lesson, different from the previous one.*

Based on the test results, semi-structured interviews and documentation during the research showed that: in question number 1 only S1 answered the question on the target problem correctly, even though the student knew the concept used using similarity but the answer was obtained in the expected way. In question number 2 only S2 was wrong in answering the question. He was able to solve the source problem, but could not solve the target problem because he forgot the method that should be used to solve the problem. In question number 3 S2 and S3 solved the source problem correctly, but both were wrong in solving the target problem.

At the encoding component, students are generally able to recognize basic information and state formulas related to the source problem, although their conceptual understanding is still limited. At the inferring component, students can obtain calculation results for several problems, but are unable to clearly explain the process or reason for using the formula. Furthermore, at the mapping component, students experience difficulty in linking the source problem with the target problem, as evidenced by inaccuracies in determining the formula. At the applying component, students are not yet able to apply analogies correctly and consistently, as indicated by confusion in solving problems, ignorance in determining initial steps, and incomplete or inappropriate answers to the given problem.

Based on the analysis results, students' analogical reasoning is still considered low. At the encoding component, students are only able to recognize some initial information and state basic formulas, such as the formula for the area of a square, but their understanding of the formula's meaning is still limited. At the inferring component, students can obtain calculation results for several problems, but are unable to clearly explain the process or reason for using the formula. Furthermore, at the mapping component, students experience difficulty in linking the source problem with the target problem, as evidenced by inaccuracies in determining the formula. At the applying component, students are not yet able to apply analogies correctly and consistently, as indicated by confusion in solving problems, ignorance in determining initial steps, and incomplete or inappropriate answers to the given problem.

Errors in analogical reasoning can occur when a comparison between two cases ignores important differences that are actually relevant to the conclusions drawn, resulting in a weak or misleading analogy (Huxley, 2007). The low analogical reasoning ability of students in this study was not solely caused by a weak mastery of mathematical concepts, but also by the ineffectiveness of learning that specifically trains transfer skills and relational thinking. Students tend to be accustomed to procedural learning and memorization, making it difficult to connect relationships between concepts.

These findings demonstrate the need to develop learning models that place greater emphasis on systematically designed analogical reasoning. Analogical reasoning plays a crucial role in learning because it requires students to relate new material to previously learned concepts. Through this process, students not only recall previous material but also develop a deeper understanding of the relationships between concepts. This allows students' abilities in each subject to develop optimally and sustainably. Strategies such as providing diverse source-target problems linked to direct experience, using visual representations, scaffolding, and reflective discussions need to be implemented to support the development of analogical reasoning components, especially in the inferring, mapping and applying processes.

IV. CONCLUSION

Based on the research results, it can be concluded that junior high school students' analogical reasoning ability in the material of flat-sided solid figures is still relatively low. The results show that students are relatively capable of encoding basic information, especially on similarities within a single topic. However, at the inferring, mapping, and applying components, students still experience various obstacles, especially in recognizing relational similarities and transferring the analogy process to different contexts. The similarity of processes between topics is the most difficult indicator for students, while similarities related to everyday life provide greater opportunities for students to build analogies, although they are still intuitive and not fully conceptual.

The results of this study confirm that the development of analogical reasoning requires learning that explicitly trains its four components in an integrated manner. Thus, the analysis of students' analogical reasoning can be seen as an important foundation in developing a more meaningful mathematics learning model, especially in the material of flat-sided solid figures. This study has limitations, namely, the research subjects were limited to three students with the highest mathematics scores in each school and the research focus only examined the analogical reasoning aspect of the material on flat-sided solids. Nevertheless, this study contributes to the field of mathematics education by enriching the study of analogical reasoning and can serve as a reference in understanding students' mathematical abilities.

Based on the research findings, the following suggestions can be put forward: First, mathematics teachers are advised to design learning that explicitly trains students in analogical reasoning through comparison activities, the use of visual representations, and the association between concepts and everyday life contexts. Teachers also need to provide guidance at the inferring, mapping, and applying components so that students are able to construct and apply analogies appropriately.

Second, for learning developers and mathematics education researchers, the results of this study can serve as a basis for developing learning models or learning strategies oriented toward strengthening analogical reasoning, particularly by integrating experiential and visual learning. These findings also contribute to the development of theoretical studies on the role of analogical reasoning in mathematics learning.

Third, for future researchers, it is recommended to conduct further research by implementing a learning model oriented towards analogical reasoning developed from the results of this study, as well as examining its influence on students' conceptual understanding and problem-solving abilities in other mathematical materials. Furthermore, further research could involve broader subjects and contexts to strengthen the generalizability of the findings.

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