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Students' Analogical Reasoning in Solving Geometry Problems Viewed from Visualizer's and Verbalizer's Cognitive Style

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ABSTRAK

Banyak penelitian yang menyatakan rendahnya kemampuan pemecahan masalah geometri siswa di Indonesia. Tujuan penelitian ini adalah mengkaji penalaran analogi siswa dalam menyelesaikan masalah geometri ditinjau dari gaya kognitifnya. Penelitian ini merupakan penelitian kualitatif deskriptif yang melibatkan 32 siswa kelas X SMA. Metode pengumpulan data yang digunakan adalah tes, angket, dan wawancara. Teknik analisis data menggunakan analisis deskriptif kualitatif. Hasil penelitian menunjukkan bahwa penalaran analogis siswa dengan gaya kognitif visualizer lebih unggul dibandingkan penalaran analogis siswa dengan gaya kognitif verbalizer dalam menyelesaikan masalah geometri. Siswa dengan gaya kognitif visualizer dapat mencapai empat komponen penalaran analogis: encoding, inferring, mapping, and applying. Siswa dengan gaya kognitif verbalizer, hanya mencapai dua komponen saja yakni encoding dan inferring. Implikasi penelitian ini adalah perlunya pendidik untuk mengidentifikasi gaya belajar masing-masing siswa yang dapat dilakukan melalui asesmen awal pembelajaran dan memberikan stimulus pembelajaran berdiferensiasi kepada siswa sesuai dengan gaya kognitif mereka. Penguatan pada siswa dengan gaya kognitif verbalizer perlu lebih ditekankan pada saat proses mapping dan applying diantaranya dengan memberikan scafolding yang sesuai dan memberikan kesempatan siswa untuk mengungkapkan strategi pemecahan masalah secara lisan, membelajarkan materi dengan menunjukkan peta konsep masalah, dan memperbanyak latihan soal yang lebih variatif.

ABSTRACT

Many studies state that students' geometric problem-solving abilities in Indonesia are low. This research examines students' analogical reasoning in solving geometric problems in terms of their cognitive style. This descriptive qualitative research involves 32 class X high school students. The data collection methods used were tests, questionnaires, and interviews. The data analysis technique uses qualitative descriptive analysis. The results showed that the analogical reasoning of students with a visualizer cognitive style was superior to the analogical sense of students with a verbalizer cognitive style in solving geometric problems. Students with a visualizer cognitive style can achieve four components of analogical reasoning: encoding, inferring, mapping, and applying. Students with a verbalizer cognitive style only achieve two parts: encoding and inferring. The implication of this research is the need for educators to identify each student's learning style, which can be done through initial learning assessments and providing differentiated learning stimuli to students according to their cognitive style. Strengthening students with a verbalizer cognitive style needs to be emphasized more during the mapping and applying process, including providing appropriate scaffolding and allowing students to verbally express problem-solving strategies, teaching material by showing problem concept maps, and increasing practice on more varied questions.

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1. INTRODUCTION

One of the subjects that students in formal education must learn is mathematics. Mathematics is a basic science that has an important role in everyday life and the development of science and technology (Ikawati & Kowiyah, 2021; Moh'd et al., 2021; Tolentino, 2020). However, in reality, many students think mathematics is a difficult subject because there are too many formulas that sometimes they don't know where the formulas come from (Gabriel et al., 2020; Kusmaryono et al., 2019; Tanudjaya & Doorman, 2020). One of the goals of studying mathematics is to be able to solve problems which includes several skills in handling these problems, but there are still many students who do not understand even the difficulties of mathematics (Nemeth et al., 2019; Nurlaily et al., 2019). Learning mathematics is an activity that includes problem solving. The process of solving problems includes applying previously acquired knowledge, skills, and understanding to satisfy the requirements of a new situation, all of which call for reasoning (Rahman, 2019; Tambunan, 2019). Problems in learning mathematics are generally stated in math problems. But not all mathematical problems will be a problem for students. A mathematical problem must meet three criteria, namely: first, individuals must accept the problem. Second, they must face blocks and not see the process of solving it directly. Third, they must actively explore different approaches to the problem. So a mathematics problem is said to be a problem if it meets certain criteria and in its completion uses non-routine procedures and the solution is not immediately found (Kurniawan et al., 2022; Öztürk et al., 2020).

The importance of problem solving capabilities has not been accompanied by the expected results. Facts in the field show that the ability to solve students' problems in Indonesia is still low. This is based on many research that reveals the low ability of students' mathematical problem solving (Ayyubi et al., 2018; Fitria, 2018; Sapitri et al., 2019; Shodikin et al., 2021). With a score of 371, Indonesia was placed 72 out of 77 nations in 2018, significantly lower than the average reading skill score across all OECD countries, which was 487 (Schleicher, 2019; Shodikin, et al., 2020). While the average for mathematical ability is 379, this is much below the OECD state average score of 489, which is typical for all countries. This demonstrates that Indonesian pupils still have limited reading and mathematics skills. Geometry is one of the mathematical concepts examined. One of the mathematics teaching tools that has been used since childhood is geometry. Students have learned about several flat shapes, when students were still in elementary school, students began to be introduced to various flat shapes such as squares, triangles, parallelograms, and circles. However, student geometry learning outcomes in Indonesia are also low. This can be seen from several studies that show the low geometric abilities of students in Indonesia (Masikhah et al., 2021; Muslimin & Sunardi, 2019; Nisa & Dwiningsih, 2022; Sulistyorini, 2018).

One of the mathematical problems solving is solving geometric problems. Geometry issue solving is a psychological (particularly intellectual) activity that seeks answers to geometric difficulties faced by integrating all mathematical information (geometry) that has been acquired (Friston et al., 2020; Hwang & Hu, 2013). Furthermore, reasoning is very necessary for solving mathematical problems including solving geometric problems (Buckley et al., 2019; Minda, 2020; Setiawan & Sa'dijah, 2020). One method of reasoning is by using an analogy. An analogy is a person's ability to see the attachment relationship between objects and ideas which are then used to obtain something else (Herawati & Akbar, 2019). So analogical reasoning is a thinking process that maps from one structure that is already known, to another structure that must be concluded based on its similarities. Analogical reasoning is very important because it helps in problem solving. Analogical thinking is an incredibly significant technique of thinking for developing views and identifying answers (Isoda & Katagiri, 2012). Furthermore, various studies show that parallels may boost learning accomplishment and students' thinking abilities and are highly effective in learning (Brookman-Byrne et al., 2019; Kristayulita, 2021; Lailiyah et al., 2022; Vogelaar & Resing, 2018).

In addition to analogical reasoning, cognitive style is one of the variables that might impact problem-solving activities. Cognitive style influences learning, particularly problem solving, since different cognitive styles lead to varied methods of absorbing and processing information (Chasanah, 2020a; Surur et al., 2020; Sutama et al., 2021). There are several cognitive styles, including visualizer and verbalizer cognitive styles. Cognitive styles based on a person's practice of employing his sensory organs separate into two categories: visualizers and verbalizers (McEwan & Reynolds, 2007).

A visualizer's cognitive type is more likely to acquire, analyze, retain, and utilize information in the form of images and visuals. A cognitive verbalizer prefers to receive, analyze, store, and utilize information in the form of text or written language. The students with a cognitive visualizer style tend to receive information in learning that is visual in nature (eg graphs, pictures, and diagrams), whereas those students with a cognitive visualizer style prefer verbal information that can be read or listened. This variation in cognitive approach undoubtedly affects the tactics employed in problem solving in mathematics. Students with diverse cognitive styles will undoubtedly employ distinct problem-solving procedures, resulting in variances in pupils' critical thinking abilities (Nur & Palabo, 2018; Pradiarti & Subanji, 2022; Ratna & Utami, 2018). Even though analogical reasoning and cognitive style have an important role in solving mathematical problems, no specific research has been found to discuss how students' analogical reasoning processes in solving geometric problems in terms of their cognitive style. Previous research related to analogical reasoning in problem solving more in terms of gender differences (Ni'mah et al., 2022), schema process (Kristayulita, 2021; Kristayulita et al., 2020), children's potential (Vogelaar et al., 2019; Vogelaar & Resing, 2018), Metacognition (Wang et al., 2022; Wang & Han, 2017), and creative expertise (Dumas et al., 2021).

Analogical reasoning in solving geometric problems in terms of learning style but from the point of view of category analysis (Ramdhani et al., 2019). The relationship between the two has also been discussed, but in a different scope of problems, namely trigonometry, algebra, and indirect problems (Azizah et al., 2021; Kristayulita, 2021; Lailiyah et al., 2022). Reflecting on the importance of paying attention to analogical reasoning in solving geometric problems and the indications of the influence of students' cognitive styles in solving mathematical problems, it is important to conduct a study on the analysis that links the two. The purpose of this research is to assess students' analogical thinking in solving geometric problems in terms of cognitive style, particularly visualizer and verbalizer cognitive styles.

2. METHOD

This study took a qualitative approach using a descriptive case study. The method used in this research is a case study in which the researcher tries to find out directly by analyzing students' analogous reasoning abilities by studying existing cases (Kristayulita, 2021; Kristayulita et al., 2020). To understand students' analogical reasoning, it is required to analyze the outcomes of student work to gather more detailed information to characterize students' analogical reasoning in solving problems on geometry material. This research involved 32 students from 10th grade at a senior high school in Lamongan Regency in filling out the cognitive style questionnaire and solving geometry problems. This research has obtained permission from the school where the research was carried out to collect the necessary data. Consent by students has also been given. This is the basis for the protection and well-being of the participants. The cognitive style questionnaire was used to group students into cognitive visualizer and cognitive verbalizer styles (Hasan, 2019; McEwan & Reynolds, 2007). Meanwhile, geometric problems were used as a basis for exploring students' analogical reasoning processes through problem-based interviews. It was found that 18 students had a visualizer learning style and 14 students had a verbalizer learning style.

Furthermore, each of the two students representing the two groups were selected with the highest score criteria to be conducted in-depth interviews. The interview guide was developed to clarify the results of student answers, analyze student difficulties and analyze students' understanding of analogical reasoning questions. These results were also combined with field notes obtained during the implementation of the research. The test items are prepared based on the criteria for analogical reasoning questions, namely the type of source problem and target problem, and based on components of analogical reasoning including four things, namely: encoding, inferring, mapping, and applying (Sternberg, 2019). The indicators for the analogical reasoning component are described in Table 1.

Table 1. Indicators of the Analogical Reasoning

No	Component	Indicators
1	Encoding	Identify each form of analogy with the coding characteristics of each problem
2	Inferring	Look for relationships among known elements in the source problem
3	Mapping	Connecting the source problem and the target problem by building a relationship drawing conclusions on the similarity of the relationship
4	Applying	Choose the correct answer to complete the analogy

3. RESULT AND DISCUSSION

Result

Based on the data obtained, both data from analogy ability tests, field notes, and interviews, students' analogical reasoning can be explained in terms of cognitive style in Table 2.

Table 2. Description of Students' Analogical Reasoning Abilities in Terms of Cognitive Style

No	Components of analogical reasoning ability	Cognitive style	
		Visualizer	**Verbalizer**
1	Encoding	Students with the cognitive visualizer style are already able to identify the characteristics or structure of the source problem and target problem well, although some are still incomplete in their writing. In other words, visualizer cognitive style students have mastered the encoding component in analogical reasoning.	Students with the cognitive verbalizer style may already recognize the qualities or structure of the source and target problems, while some of their writing is still incomplete. In other words, cognitive verbalizer pupils have mastered the encoding component of analogical reasoning.
	Inferring	Students with a cognitive visualizer style may solve source problems and see linkages in source difficulties. Students with the cognitive visualizer style, in other words, have mastered the inferring component of analogical reasoning.	Students with the cognitive verbalizer style are good at solving source problems and looking for links in source difficulties. Students with the cognitive verbalizer style, in other words, have mastered the inferring component of analogical reasoning.
	Mapping	Students that have the cognitive visualizer personality might explore for connections or parallels between the source and target problems. In other words, pupils who have the cognitive visualizer personality have mastered the mapping component of analogical reasoning.	Students with the cognitive verbalizer personality style are unable to identify correlations or similarities between the source and target problems. Female pupils, in other words, have not grasped the mapping component of analogical reasoning.
	Applying	Students with the cognitive visualizer style are able to solve target problems based on the similarity of the process with the source problem and provide the right answer choices for the target problem and can provide similarities or analogies even though some are not thorough in the process. In other words, students with the cognitive visualizer style have already mastered the components of analogical reasoning.	Students with cognitive verbalizer styles are unable to address the target problem based on process similarities with the source problem because they cannot detect similarities or parallels with the source problem. In other words, pupils who use cognitive verbalizer styles have not mastered the components of analogical reasoning.

Based on the results of the tests and interviews, it was found that the analogical reasoning abilities of the students were as shown in Table 3.

Table 3. Students' Analogical Reasoning Abilities in Terms of Cognitive Style

No	Subject	Components of analogical reasoning			
		Encoding	**Inferring**	**Mapping**	**Applying**
1	Visualizer	√	√	√	√
2	Verbalizers	√	√	--	--

Table 3 shows that students with the visualizer cognitive style are able to achieve the four components of analogical reasoning, namely encoding, inferring, mapping, and applying. While students with a verbalizer learning style are only able to achieve two components, namely encoding, and inferring. In the encoding process, it can be seen that the visualizer cognitive style students have mastered the encoding component in analogical reasoning. This demonstrates that pupils with the visualizer cognitive type can translate the qualities or structure of the source and target problems into mathematical symbols.

The results of analogical reasoning tests and more in-depth interviews with the subject of the visualizer's cognitive style demonstrate this. Students with the visualizer cognitive type have written well the qualities or structure in the source problem and the target problem, both what is known and what is being requested, in the exam questions. In addition to the encoding component, visualizer cognitive style students have also mastered the second component in analogical reasoning, namely inferring. The subject of the visualizer cognitive style student has successfully solved the source problem and understands the relationships that exist in the source problem. According to Table 3, the topic of the cognitive visualizer style kids has mastered the inferring component. For the third component of analogical reasoning, namely mapping, cognitive visualizer style students have been able to find relationships or similarities that exist between the source problem and the target problem, namely the similarity of using the Pythagorean concept in working on the problem. The subject of the visualizer cognitive style has been able to find relationships or similarities that exist in the source problem and the target problem. In the fourth component of analogical reasoning, namely applying, the visualizer cognitive style students are able to solve target problems and provide answers correctly and are able to write down similarities or analogies. Ultimately, students studying the visualizer cognitive style have mastered the four components of analogical reasoning, which are encoding, inferring, mapping, and applying.

The cognitive verbalizer type students have mastered the encoding component of analogical reasoning. This demonstrates that pupils with the cognitive verbalizer style can translate the qualities or structure of the source and target problems into mathematical symbols. The findings of analogical reasoning tests and more in-depth interviews on the issue of the verbalizer's cognitive style demonstrate this. Even if the writing is not quantitative, students with the cognitive verbalizer style have expressed effectively the features or structure in the source problem and the target problem, both what is known and what is asked, in the exam questions. Students with the verbalizer cognitive style have also mastered the second component of analogical reasoning, namely inferring. The subject of the verbalizer cognitive style student has been able to solve the source problem well and is able to know what relationships exist in the source problem.

Unlike the cognitive visualizer style students, the cognitive verbalizer style students have not been able to master the third component, namely mapping. Students in the cognitive verbalizer style mean that they have not been able to establish correlations or parallels between the source and target problems. There is minimal difficulty in identifying commonalities between the source and target problems. Therefore, the cognitive verbalizer style still does not feel it has discovered these commonalities. In the fourth component of analogical reasoning, namely applying, students in the cognitive verbalizer style are also not able to solve target problems and provide answers correctly and have not been able to write down similarities or analogies. This is because pupils with the verbalizer cognitive style have not been able to discover the link that exists between the source problem and the target problem (mapping), therefore the target topic is not perfect and there are still flaws in fixing the problem. Furthermore, students with the verbalizer cognitive style do not write down their responses in detail while tackling target issues, but students with the visualizer cognitive style do. This suggests that pupils with the cognitive verbalizer style are only proficient in two aspects of analogical reasoning: encoding and inferring.

Discussion

This study aims to determine students' analogical reasoning in solving geometric problems in terms of cognitive style. This review of analogical reasoning is described from its components namely encoding, inferring, mapping, and applying. While the intended cognitive style is a visualizer and verbalizer cognitive style. Based on the results of the study it was shown that the students' analogical reasoning abilities with the cognitive visualizer style were better than those with the cognitive verbalizer style in solving geometric problems. This is because geometric concepts such as the Pythagorean concept are concepts that need to be described, so students with the visualizer learning style are better at understanding geometric concepts, such as Pythagoras (Azizah et al., 2021). In addition, students with the visualizer cognitive style also benefit from questions that present a lot of information that comes from the images given in the questions (Azizah et al., 2021; Hasan, 2019).

Cognitive styles connected to a person's practice of employing his sensory organs are separated into two groups: visualizers and verbalizers (Martinsen & Furnham, 2019; McEwan & Reynolds, 2007). A visualizer's cognitive style makes it simpler to acquire, process, retain, and utilize information in the form of visuals and graphics (McCunn & Cilli-Turner, 2020; Pan et al., 2020). A cognitive verbalizer is more likely to receive, analyze, store, and utilize information in the form of text or written language. Geometry problems that require pupils to solve issues in the form of drawings and forms have specific benefits for students with a visual cognitive style. If seen from the similarity of the achievements of these two students' cognitive styles, both students with visualizer and verbalizer cognitive styles have similar skills in encoding and inferring components of analogical reasoning. This indicates that students with these two cognitive styles do not have significant problems in these two stages. However, in the mapping component, students with the cognitive verbalizer style have problems. The mapping process which emphasizes the process of visualization and simplification is not suitable for the verbalizer's cognitive style which tends to describe. While students with a visualizer cognitive style who are familiar with images, graphs, and simplifications benefit more from this component. Obstacles faced at the mapping stage by students with the verbalizer learning style also resulted in obstacles at the next stage, namely applying. An incomplete description of the problem results from the mapping stage making it difficult for students to determine the right problem-solving strategy. This makes a quite logical and acceptable reason why students with the visualizer cognitive style are superior in solving geometric problems that require trial and error analysis and visualizing problems. Even so, students with a verbalizer style actually benefit from the types of questions that are of the long reading type. The findings of this study are consistent with the findings of Hasan's research, which show that there are differences between visualizer and verbalizer subjects when it comes to understanding the problem, developing a problem- remediation plan, implementing a problem-solving plan, and re-examining the results obtained (Hasan, 2019).

Students with visualizer cognition tend to employ picture information to develop alternate answers, whereas those with verbal cognition use already established formulae (Fatmalasari & Siswono, 2020; Hasan, 2019). Another thing that supports this is that visualizer subjects tend to like writing and scribbling to analyze answers, while verbalizer subjects tend to describe an analysis of answers without writing them down (Hasan, 2019; Toomey & Heo, 2019). The existence of a cognitive style needs attention for teachers in teaching students so that it makes it easier for them to solve mathematics problems (Surur et al., 2020; Sutama et al., 2021). In addition, students' cognitive styles also influence students written mathematics communication skills. Different students' cognitive styles show different levels of mathematical communication skills (Chasanah, 2020b). However, this difference is also influenced by the learning model and problem solving method used. Learning styles and problem-solving techniques together significantly influence students' academic success in mathematics (Gusau et al., 2019; Surur et al., 2020).

The implication of this research is the teachers need to develop mathematics learning through analogical reasoning so that it can assist students in linking the knowledge they are dealing with previously acquired knowledge through an understanding of similarity by not ignoring the different cognitive styles of students, especially students with visualizer and verbalizer cognitive styles. To teach mathematics that incorporate analogical reasoning according to students' cognitive styles, teachers can start by identifying the type of cognitive style of each student, whether visualizer or verbalizer, through a the initial learning assessment. Through information on cognitive style tendencies obtained, teachers can provide different treatment to students according to their cognitive style to optimize the learning process. Students who have a tendency to visualizer cognitive style must be accommodated with learning that utilizes the visual senses in learning, such as the use of visual aids, teaching aids, pictures, graphs, diagrams, charts, videos, animations, multimedia presentations, or concept maps to help students visualize and understand relationships between concepts. This visualization can serve as a bridge for students to connect new information with previous knowledge (Gusau et al., 2019; Surur et al., 2020).

Giving assignments or visual projects is also highly recommended. Nonetheless, teachers also need to ascertain and consider the individual needs and preferences of students by observing and communicating with them regularly. By incorporating strategies that emphasize the use of visuals, teachers can help students with the visualizer cognitive style develop a strong understanding of mathematics. Furthermore, for students with the cognitive verbalizer style, giving clear and structured oral explanations about the mathematical concepts being studied is very necessary (Jena, 2014; Martinsen & Furnham, 2019). Students with the verbalizer cognitive style tend to understand the material more verbally. Use simple and clear language to make it easier for them to understand. Learning that accommodates group discussions can also be used for students with a cognitive verbalizer style. They tend to absorb information through conversation and social interaction. Therefore, teachers need to provide opportunities for group discussions, where they can share and discuss their understanding of mathematical concepts. This discussion will help them clarify their thinking and deepen understanding through conversations with classmates. Open-ended questions can also be asked to stimulate thought and discussion (Herdiman, 2017; Koriyah & Harta, 2015). Open-ended questions encourage verbalizer students to think verbally and construct their own mathematical arguments (Oliveira et al., 2021; Sari et al., 2016). This helps them develop a deeper understanding of mathematical concepts. Giving written assignments such as explaining concepts, solving math problems in writing, or making a summary of the math topic being studied can help them organize their thinking and strengthen understanding. The use of notes or concept maps can also be applied to students with the verbalizer cognitive style. They may benefit from taking notes or concept maps during math lessons. Let them take notes by describing concepts, creating definitions, and writing related examples or formulas. This will help them organize information verbally and make it easier for them to repeat material. In addition to the written exam, give verbalizer students the opportunity to demonstrate their understanding orally. For example, the teacher could hold an oral question-and-answer session in class or assign an oral presentation assignment on a particular math concept. Providing verbal feedback is also highly recommended. Students with the cognitive verbalizer style often value direct and verbal feedback. Teachers need to take time to verbally provide feedback to them on their progress in understanding math concepts and possible improvement steps.

Although this research has presented comprehensive results on how students' analogical reasoning in solving geometric problems is viewed from their cognitive style and what the implications are for learning, we realize that the subjects we use are high school students who, based on cognitive development theory, are already able to think formally operationally. The results may be slightly different if it is carried out on students with concrete operational developmental stages or more basic ones. This at the same time provides opportunities for further research to see how students' analogous reasoning in solving problems in terms of their cognitive style for other stages so that it will fully show how at each stage of cognitive development in students.

4. CONCLUSION

Based on the findings of the discussion on the description of analogical reasoning abilities in terms of cognitive style, it is possible to conclude that the analogical reasoning abilities of students in the cognitive visualizer style are better than those of students in the cognitive verbalizer style. According to the study's findings, pupils with the cognitive visualizer style have mastered the four components of analogical reasoning, namely encoding, inferring, mapping, and applying. Students with the cognitive verbalizer style, on the other hand, only learned two components of analogical reasoning ability: encoding and inferring.

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