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Spatial Reasoning of Junior High School Students in Solving Spatial Problems as Viewed From Differences in Cognitive Styles

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Abstract

Spatial reasoning is a crucial component in mathematics education, particularly in solving geometry problems that require visualization and mental manipulation of objects in space. This study aims to describe the spatial reasoning of junior high school students based on their cognitive styles, namely field independent (FI) and field dependent (FD). The study employed a qualitative approach with a descriptive method. Data were collected through students' solutions to geometry tasks involving three-dimensional shapes and in-depth interviews with two selected subjects representing each cognitive style. The findings indicate that the field-independent subject demonstrated a comprehensive visual representation of geometric objects, formulated problem-solving steps systematically, and exhibited flexibility in positioning objects from various perspectives. However, their ability to mentally rotate objects and evaluate alternative strategies remained underdeveloped. On the other hand, the field-dependent subject showed an initial understanding of object structure. It could construct general problem-solving strategies but struggled with spatial manipulation, maintaining proportions between parts, and engaging in critical reflection of visual representations and solutions. These findings suggest that cognitive style significantly influences students' spatial reasoning in solving geometry problems, implying that instructional strategies in mathematics, particularly in STEM contexts, should be tailored to cognitive style differences to enhance visual-spatial and metacognitive skills. However, the small number of subjects, the limited scope of geometry tasks, and the reliance on self-reported thought processes restrict the generalizability of the findings, indicating the need for further research with larger and more diverse samples.

INTRODUCTION

Reasoning is one of the skills that students need to have in learning mathematics. (NCTM, 2000) States that reasoning and proof should be part of student learning in mathematics at all levels. (Mukuka et al., 2023) State that reasoning skills improve students' mathematical knowledge. One form of reasoning that is highly relevant in mathematics is spatial reasoning, as it helps individuals understand concepts deeply, build connections between concepts, and apply that understanding in various situations (Pavlovičováa & Valéria, 2015). Spatial reasoning allows students to visualize and manipulate objects in their minds, thereby facilitating a more concrete understanding of complex mathematical concepts (Choi & Kim, 2021)Spatial reasoning not only helps students solve geometry problems but also builds a deeper conceptual understanding of spatial concepts (Choi & Kim, 2021).

Spatial reasoning is important for geometry and the development of broader problem-solving skills in mathematics. They consider it one of the fundamental aspects of solving geometry problems, as many geometry tasks require understanding the spatial relationships between objects or shapes and the ability to imagine changes in the shape or position of objects in space. (Kozhevnikov, 2007) Spatial reasoning is the ability to understand and manipulate objects or information in space through mental visualization and to combine and transform spatial information accurately when solving mathematical problems. Good spatial reasoning skills are closely related to superior performance in solving geometry-related problems, including understanding the movement of objects in space, changes in reference frames, and interpreting graphs.

Various factors can influence students' spatial reasoning, one of which is differences in cognitive styles (Ramful et al., 2016). Students' different cognitive styles play an important role in influencing how they think and reason, especially in the context of problem-solving solving (Kondo & Osaka, 2004). Cognitive style refers to an individual's preferences in processing, understanding, and using information. These differences reflect how students interpret problems, develop strategies, and make decisions. Witkin (1973) Distinguishes cognitive styles into two main categories: Field-independent (FI): Individuals with this cognitive style can separate important elements from the context or background. They tend to be independent in processing information, analytical, and more adept at mentally manipulating data. Field-dependent (FD): Individuals with this cognitive style rely on context or background to understand information. Environmental elements influence them more, and they have difficulty separating the main information from supporting elements. FI and FD cognitive styles closely relate to how individuals process visual information and identify important elements in a complex context. These cognitive styles are often seen in individuals more comfortable working collaboratively or in clearly structured situations. In line with this (Williams et al., 2010) Differences in students' cognitive styles play a crucial role in influencing their thinking patterns and reasoning, especially in problem-solving.

Febriana (2015) Revealed that junior high school students with low spatial abilities face difficulties when solving three-dimensional geometry problems. This aligns with the primary focus of the secondary school curriculum, which emphasizes students' ability to identify or discover and understand the structure of an object or situation that is not yet fully known. In line with this, Yilmaz (2017) Shows a positive relationship between spatial abilities and mathematics learning achievement. In other words, the higher a person's spatial abilities, the greater the likelihood of them achieving better results in mathematics, particularly in understanding and solving complex geometry problems.

The primary focus of this research is to investigate junior high school students' spatial reasoning in solving three-dimensional geometry problems, viewed through the lens of their cognitive styles—field independent (FI) and field dependent (FD). Spatial reasoning is chosen as the core focus because it bridges visualizing mathematical concepts and applying them to problem-solving contexts, particularly in geometry, where understanding spatial relationships and mental manipulation of objects are essential. Cognitive style is a differentiating factor in exploring how FI and FD students process visual-spatial information, construct problem-solving strategies, and overcome challenges in mentally transforming objects. By analyzing these patterns, this study aims to provide a detailed description of the strengths and weaknesses associated with each cognitive style, offering insights into how teaching strategies in mathematics, especially within STEM-oriented instruction, can be tailored better to support the development of students' spatial reasoning abilities.

LITERATUR REVIEW

Spatial Reasoning

According to the Big Indonesian Dictionary (KBBI), reasoning is a mental process of developing thoughts based on several facts or principles. In line with this, (Ma'Rifatin et al., 2019) Reasoning is a student's cognitive ability to organize and process existing information to draw logical conclusions. Reasoning is a cognitive process that involves the ability to establish logical relationships between statements or information. One important element in reasoning is using statements or expressions such as "if..., then..." which allow a person to connect a condition with its effect or consequence. In this context, reasoning does not only focus on concluding given facts, but also includes the process of making assumptions or hypotheses based on available information (Mason, 2001). (Kilpatrick & Swafford, 2017) Mathematical reasoning is the ability to draw conclusions based on applicable mathematical principles, present valid arguments, and connect concepts to solve problems creatively and logically. This shows that reasoning is related to the final result and a deep and structured thinking process. Based on this description, this research focuses on the logical thinking process in concluding.

Spatial reasoning is an important aspect of mathematics learning, especially in solving three-dimensional geometry problems. Several previous studies have shown a relationship between spatial ability and success in solving mathematical problems. (Van Garderen, 2006) Examined the relationship between spatial visualization and problem-solving ability in students with varying levels of ability, but his research focused on only one category of spatial reasoning. (Rizki Kurniawan Rangkuti & Dwi Juniati, 2022) Research covered three aspects of spatial reasoning—visualization, orientation, and spatial relations—but emphasized the influence of mathematical ability on spatial ability rather than the implementation of spatial reasoning in problem solving. Meanwhile, (Fujita et al., 2022) Identified core spatial skills that play a role in solving three-dimensional geometry problems, but did not examine in depth the role of each spatial reasoning category in solving mathematical problems. Given these limitations, this study occupies a strategic position by focusing on spatial reasoning in solving three-dimensional mathematical problems and comprehensively examining all three categories of spatial reasoning (visualization, orientation, and spatial relations), rather than just one. This study also considers differences in students' cognitive styles as factors that may influence the spatial reasoning process in problem-solving, thereby aiming to contribute new insights into understanding students' thinking characteristics more deeply.

Spatial reasoning is a cognitive process that enables individuals to use mental abilities to understand, represent, and manipulate spatial relationships between objects around them. This process is highly dependent on mental models, internal representations resembling the layout, shape, or spatial configuration of objects or situations (Byrne & Johnson-Laird, 1989). Additionally, (Lowrie et al., 2016) Spatial reasoning is understanding, visualizing, and manipulating relationships between objects or representations within space. (Clements & Battista, 1992) In the Handbook of Research on Mathematics Teaching and Learning, spatial reasoning is the understanding and management of relationships between objects or shapes in space. (Kozhevnikov et al., 2007) Spatial reasoning is the ability to visualize, interpret, and manipulate spatial information regarding problems involving objects or movements in space. In line with this, (Kondo & Osaka, 2004) Defines spatial reasoning as an individual's ability to seek visuals and form and manipulate mental representations of these elements.

Choi and Kim (2021) Explain that spatial reasoning is the skill of accurately understanding and managing space. This ability includes accurately recognizing shapes and objects, imagining and understanding changes in geometric objects in the mind, and representing these objects in real form. Additionally, this ability also involves the ability to represent these objects visually. This aligns with the view of (Williams et al., 2010) It is stated that spatial reasoning is related to the representation and use of objects and their relationships with the world. It is understood topologically and geometrically in two and three dimensions, with or without time as the fourth dimension. Spatial reasoning is the process of thinking logically and systematically to conclude from known information or premises related to spatial visualization, mental rotation, and spatial orientation.

The following table presents the indicators of spatial reasoning used in developing research instruments.

Table 1. Category and Indicators Spatial Reasoning

Category	*Indicators*
Spatial Visualization	Determining the visual representation of an object
	Determining the visual representation of an object after manipulation
Mental Rotation	Imagining the rotation of an object in the mind
	Determining the change in shape of an object after rotation
Spatial Orientation	Determining changes in orientation based on different perspectives

Spatial Problem Solving

Hendriana et al (2018) define a problem as a situation an individual or group faces when performing a task, where the steps to solve it are not yet fully known or available. This situation requires creative thinking and the ability to use effective problem-solving strategies to find the right solution. Siswono (2018) defines problem-solving as individuals' efforts to solve a problem by utilizing their existing knowledge, skills, and understanding. This is supported by the opinion of Krulik and Rudnick (2016), who define a problem as a condition that requires thinking and the combination of previously acquired knowledge to find a solution.

A question can be considered a problem if it contains challenges that cannot be solved through routine procedures known to the perpetrator. This is in line with the opinion (Cooney et al, 2017) who stated, "For a question to be a problem, it must present a challenge that cannot be resolved by some routine procedure known to the student." In this context, a problem encourages individuals to think outside the box, seek new approaches, or apply creative strategies that differ from conventional methods. Based on the above description, this study focuses on the problems to be discovered. Problems in this study are defined as questions individuals face when they do not have solutions or steps to find an answer.

Cognitive Style

Cognitive style refers to the unique characteristics of individuals in responding to various situations, including attitudes, preferences, and strategies that are consistently used in understanding, remembering, thinking, and solving problems (Saracho, 2016). Kozhevnikov (2007) Argues that cognitive style reflects the various ways individuals process information about their environment. Witkin (1973) Cognitive style is how individuals process information and interact with their environment to solve problems or make decisions. He introduced the concepts of field-dependent (FD) and field-independent (FI) as the main dimensions of cognitive style.

Sasongko & Siswoyo (2013) Their research focused on how students with FI and FD cognitive styles formulate math problems. FI students tend to formulate more abstract and complex problems, while FD students are more contextual in formulating problems. Kusumaningtyas et al (2017) Examined the differences in problem-solving strategies between students with FI and FD cognitive styles. The results showed that FI students tend to be more independent in identifying patterns, while FD students rely more on provided examples. These findings indicate that cognitive style influences students' approaches to solving mathematical pattern generalization problems.

This indirectly suggests that students with FI cognitive style tend to work more effectively when given freedom, while students with FD cognitive style perform better when provided additional guidance or instructions. Therefore, understanding students' cognitive styles enables the selection of appropriate teaching methods in implementing instruction. Based on the above discussion, FI and FD cognitive styles have broad applications in the field of education, so in this study, they are used as the primary focus.

Spatial Reasoning In Problem Solving

Lowrie et al. (2016) classify spatial reasoning into three main categories: mental rotation, spatial orientation, and spatial visualization. Mental rotation refers to mentally rotating objects without altering their shape or size. Spatial orientation involves understanding the position of an object relative to oneself or other objects in space. Spatial visualization encompasses the ability to mentally represent changes in an object's shape or structure when subjected to transformations such as folding, cutting, or reconfiguring. Meanwhile, in the problem-solving process, Polya (2004) outlines four systematic stages that are widely applied in mathematics learning: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) reviewing or checking the solution.

On the other hand, cognitive style reflects how students receive, process, and utilize information in solving problems. According to Shi and Qu (2021) and Riding and Rayner (1998), cognitive styles can be categorized into two main types: field dependence and field independence. Field-dependent learners tend to rely on contextual or external cues when interpreting information. In contrast, field-independent learners are more autonomous in processing information and are less reliant on their surrounding environment.

These three constructs are inherently interconnected: spatial reasoning, problem solving, and cognitive style. Spatial reasoning skills, such as mentally rotating objects or visualizing transformations, play a crucial role in effectively executing Polya's problem-solving stages, particularly in understanding and devising strategies for spatially complex problems. Cognitive style influences how these reasoning processes are employed: field-independent learners may navigate problem-solving tasks more autonomously, drawing on internal spatial representations, whereas field-dependent learners may benefit more from contextual aids or external references. Consequently, understanding the interplay between spatial reasoning, problem-solving strategies, and cognitive styles is essential for designing instructional approaches that cater to diverse learners' needs.

METHODS

This study employed a qualitative research method with a descriptive approach, aiming to provide an in-depth depiction of students' mathematical reasoning processes based on their cognitive styles in the context of mathematical problem solving. The focus was not merely on the final answers obtained by students but on the detailed mental processes they followed to arrive at those solutions. The research subjects were selected through purposive sampling from eighth-grade students who had already studied mathematical content relevant to the problem-solving tasks. Selection was based on several considerations, including the students' ability to communicate effectively, their willingness to participate in the entire research process, and their representation of the two cognitive style categories, Field Independent (FI) and Field Dependent (FD). Selecting subjects began with administering the Group Embedded Figures Test (GEFT) to classify students into FI or FD categories. Following this, a Mathematics Ability Test (TKM) was administered to ensure that all prospective participants had relatively equivalent mathematical abilities, thereby reducing the potential influence of prior knowledge differences on the reasoning analysis.

Based on the results, two students with a dominant FI tendency and two with a dominant FD tendency, all possessing comparable mathematical abilities, were chosen as the main participants. Data collection was conducted in three sequential phases. The first phase involved administering the GEFT to determine each student's cognitive style. The second phase consisted of administering the TKM to ensure comparability in mathematical ability. In the third phase, the selected participants were given mathematical problem-solving tasks designed to elicit spatial reasoning skills. In-depth interviews were conducted to gain deeper insights into their cognitive processes, which explored the strategies used by students, the challenges they encountered, and the reasoning behind their chosen approaches.

Table 2. Data Collection and Types of Data Analysis

Stage of Data Analysis	Data Source	Analysis Technique	Output Produced
Data Condensation	GEFT results, Mathematics Ability Test (TKM), written problem-solving tasks, interview transcripts	Selection, focusing, and coding of data based on indicators of spatial reasoning and cognitive style	Relevant and focused data set for further analysis
Data Display	Condensed data from all instruments	Organization of data into descriptive narratives, tables, and diagrams	Explicit representation of each subject's reasoning process according to cognitive style
Conclusion	All displayed and organized data.	Identification of reasoning patterns and comparison between the FI and the FD groups	Conclusions regarding the influence of cognitive style on spatial reasoning in mathematical problem solving

RESULTS AND DISCUSSION

The following are the results of selecting subjects with cognitive styles fi and fd of the same gender and equivalent mathematical abilities.

Table 3. Research Subject

No	Initials	Gender	Cognitive Style	TKM Score
1	GVZ	P	FI	70
2	SA	P	FD	66

Spatial Reasoning of Students with FI Cognitive Style

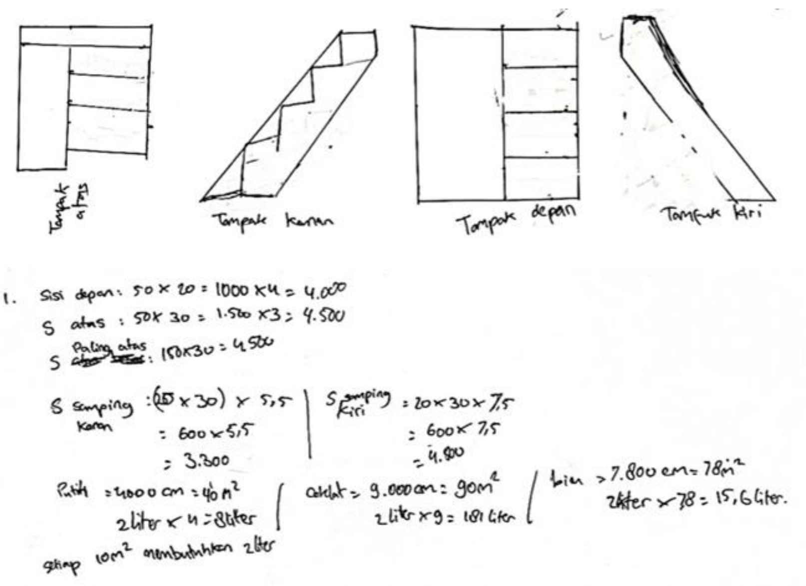

Figure 1. FI Subject Completion

The image shows four perspectives of a stepped 3D structure: top, right, front, and left. Each view outlines the shape and dimensions of the structure from different angles. Below, handwritten notes calculate the surface area of each side in cm^2 and m^2, then estimate the amount of paint needed for white, chocolate, and blue based on the assumption that 2 liters covers 10 m^2.

Problem Understanding Stage

Based on the analysis results, the subject has shown an initial understanding of the geometry objects in the problem, although not explicitly writing the known and questionable information. This understanding is reflected in his ability to explain the size of each side of the stairs and realize that each side has a different appearance, affecting the surface area calculation. This is in line with the concept of mental models proposed by Byrne & Johnson-Laird, (1989) Where individuals form an internal representation of a spatial situation without the need always to put it in writing. The subject's ability to distinguish the shape and position of the sides of the stairs indicates the involvement of spatial visualization, which is the ability to manipulate spatial information in the form of visual representations (Ramful et al., 2016; Turgut & Yilmaz, 2012)

However, there was no active use of mental rotation strategies in imagining the appearance of objects from other perspectives, indicating that the subject's spatial skills were still limited to visual recognition from one direction of view. This suggests that the ability of spatial orientation and perspective flexibility, as described by (Linn & Petersen, 1985; Ramful et al., 2016) Have not developed optimally. The subject has understood the shape and relationship between the parts of the stairs. However, it has not fully integrated the process of mental spatial manipulation, such as rotating or changing the view of objects from various orientations. Thus, at the stage of understanding the problem, the subject shows an initial capacity in spatial reasoning through recognizing shapes and structures, but needs strengthening in rotation and orientation.

Planning the Solution Stage

The subject showed mastery of spatial reasoning, reflected in his ability to develop strategies based on visual representations of objects. When the subject starts planning by determining the appearance of each side of the stairs as the basis for calculation, this shows the ability in spatial visualization, which involves managing and manipulating information in complex visual form internally (Ramful et al., 2016; Turgut & Yilmaz, 2012). This process is in line with the thoughts of Clements & Battista, (1992) Who emphasized the importance of managing spatial relationships in understanding and solving geometry problems.

Although the mental rotation process was not explicitly explained, the subject's accuracy in calculating the shape and area of the side parts of the stairs indicated that mental spatial manipulation had occurred. This supports the definition of Lowrie et al. (2016) and Linn & Petersen (1985) definition that mental rotation is the ability to imagine how the appearance of an object changes after it is rotated-this ability is important in understanding the orientation of geometric objects from an indirect point of view. The subject also demonstrated spatial orientation ability when he adjusted the size and position of the parts of the stairs based on the number of steps and the division of the plane, which reflects awareness of the relationship between elements in space from various perspectives (Linn & Petersen, 1985; Page et al., 2021)

In addition, the subject's systematic approach in determining the formula, calculating the area of each side, and estimating the amount of paint needed shows the integration between spatial ability and procedural mathematical understanding. This is in line with the thoughts of (Kozhevnikov et al., 2007) and (Buckley, J., Seery, N., Canty, 2018), which state that spatial reasoning includes not only object manipulation, but also cognitive skills in managing visual representations effectively to support problem solving. Thus, the subject has demonstrated the use of functional.

Plan Implementation Stage

The subject showed a relatively mature application of spatial reasoning, especially in visualization and understanding spatial relations. When the subject described the object viewed from each side of the stairs, including the side determined through mental manipulation, he showed mastery in the aspect of spatial visualization-that is, the ability to manipulate spatial information internally and represent it externally in the form of images (Ramful et al., 2016; Turgut & Yilmaz, 2012). Although the subject did not include the size in the picture, the accuracy of the calculation of the area of each side showed that the mental representation was stable and detailed, according to the concept of mental models described by (Byrne & Johnson-Laird, 1989)

The subject's ability to maintain consistency in size and shape when calculating surface area, even without physical manipulation, reflects mental rotation and internal spatial measurement. This is by the theory of (Linn & Petersen, 1985; Ramful et al., 2016) This states that mental rotation allows individuals to accurately anticipate changes in the position or orientation of objects through thought alone. On the other hand, the subject also demonstrated spatial orientation skills, as proposed by McGee (in Li et al., 2025), by adjusting calculations based on the position of each side of the stairs from various angles, and logically dividing and multiplying the parts of the stairs according to the number of steps seen from a particular perspective.

The overall systematic work process of the subject in connecting visual forms with calculation strategies reflects that his spatial reasoning is not only passive (observation), but also active in directing the solution steps. This is in line with the opinion of Buckley et al. (2018) that spatial reasoning includes the skills to manage and manipulate spatial relationships actively.

Looking Back Stage

The subject shows a reflective effort in evaluating the results of the visual representation that has been made, which reflects the application of spatial visualization ability, namely, reviewing mental representations and matching them with the real form of the object (Ramful et al., 2016; Turgut & Yilmaz, 2012) When the subject matched the image he drew with the image of the stairs available on the problem sheet, this is from the viewer's view. Kozhevnikov et al., (2007) Spatial reasoning involves visualizing and comparing spatial information in the context of concrete problems.

In addition, the subject's ability to compare the mental image with the actual form of the object shows that the mental model formed is quite strong (Byrne & Johnson-Laird, 1989). This process is also in line with mental rotation, although in this context it is used not to imagine a new transformation, but to verify the results obtained. Nevertheless, the subject's limitation in exploring the possibility of simpler solutions from other perspectives suggests that aspects of spatial orientation, namely the ability to imagine objects from various viewpoints and anticipate alternative views (Linn & Petersen, 1985; Pavlovičováa & Valéria, 2015) Have not fully developed flexibility.

This also supports Kim's (2021) statement that spatial reasoning includes shape recognition and the ability to represent and understand shape changes from different viewpoints, including evaluating strategy efficiency. Thus, although the subject has shown reflective ability in comparing mental and visual representations, exploring alternative perspectives and strategies still needs to be strengthened for spatial reasoning.

Spatial Reasoning of Students with FD Cognitive Style

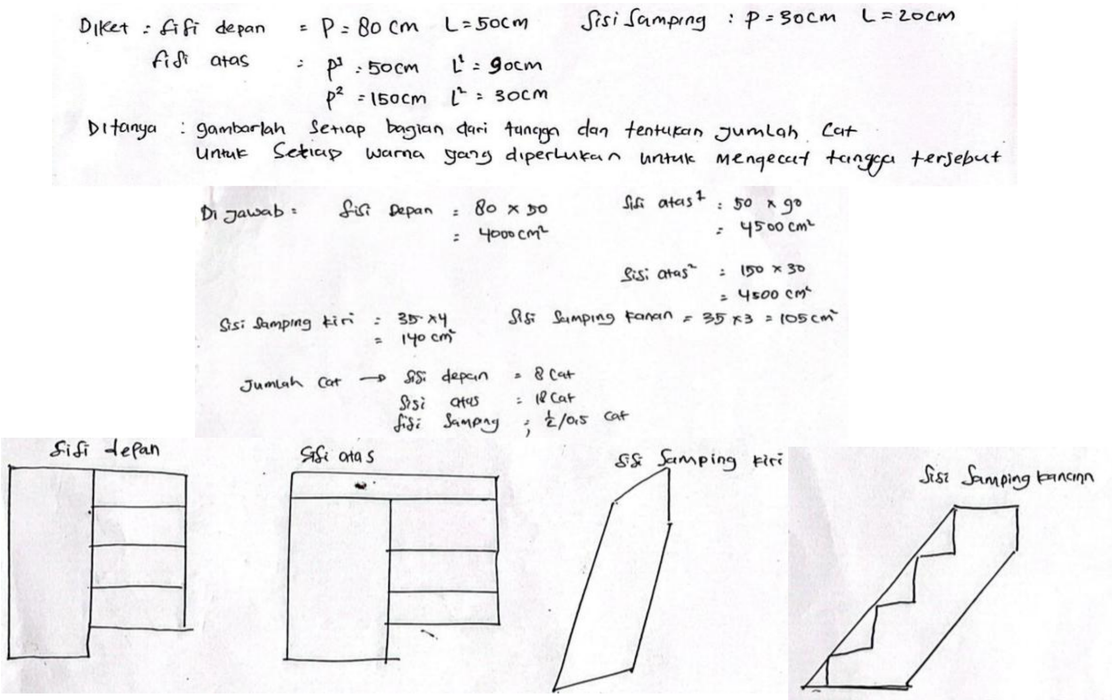

Figure 2. FD Subject Completion

The image shows a staircase-shaped object with given dimensions for each face. It includes calculations of each surface area, conversion to paint quantities, and drawings from the front, top, and both side views to support the estimation of paint needed for each part.

Problem Understanding Stage

The subject showed that he had understood the important information in the problem by mentioning the size of each side of the stairs and what needed to be calculated. This ability shows that the subject can form an initial visual representation of the given geometry object. In this case, he has used the spatial visualization process, which is the ability to manage spatial information internally and convert it into mental structures that can be used in problem-solving. (Lowrie et al., 2016; Turgut & Yilmaz, 2012). Byrne & Johnson-Laird (1989) Explain that this ability is closely related to mental models' internal spatial representations of objects, and subjects have shown that such models have been formed by recognizing the dimensions and structure of stairs.

Understanding that each side of the ladder has a different shape and must be counted separately shows that the subject has begun to recognize the differences in the appearance of objects from various perspectives. This reflects the involvement of the second indicator, namely the ability to identify that the appearance of objects will be different depending on the direction of view. According to (Kozhevnikov et al., 2007; Ramful et al., 2016), Spatial orientation involves recognizing that objects change their appearance when viewed from a certain angle, and the subject appears to have realized the importance of the viewing angle in distinguishing each side of the stairs.

However, despite the good understanding of the object's structure and perspective, the subject has not shown any prediction of the changes in the object's appearance after being rotated. He had not yet mentally manipulated the object's orientation - for example, imagining how the stairs would appear if rotated or viewed from a direction that was not directly visible. This shows that the third indicator, namely the ability to imagine changes in orientation and shape due to rotation, has not been optimally developed shape due to rotation, has not developed optimally. Whereas according to (Linn & Petersen, 1985; Turgut & Yilmaz, 2012) Mental rotation is an important part of spatial reasoning that helps individuals construct more flexible and dynamic spatial representations.

Thus, based on the three indicators of the understanding stage, it can be concluded that the subject has fulfilled the initial ability to form visual representations of objects and realize the differences in appearance from various perspectives, but has not been able to actively imagine or manipulate the shape of objects when their orientation changes. This shows that the subject's spatial reasoning at the initial stage is still static and does not fully reflect mental flexibility in managing changes in the shape and position of objects in space. Strengthening the aspects of rotation and spatial dynamics must be given so the subject can understand geometric objects more fully and contextually in real problem situations.

Stage of Planning for Completion

In developing a solution plan, the subject initially understood systematic procedures by choosing an area calculation approach using the rectangular area formula for each side of the stairs. The subject designed the work sequence logically: calculating the area of the sides one by one, adding up the total area, and adjusting the amount of paint based on the color of the side. This process reflects the activation of spatial visualization, which is the ability to manage and represent spatial information in the form of visual representations that can be applied in solving strategies, as described by (Lowrie et al., 2016; Turgut & Yilmaz, 2012) The subject had used the spatial structure of the object to functionally direct the mathematical strategy, indicating that the geometric information from the problem had been processed in an integrated manner in the form of planning.

However, when asked to describe the appearance of the stairs from the left side and the front, the subject could not produce an appropriate visual representation. This shows that the ability to imagine changes in shape due to rotation has not developed optimally. The subject has not fully sing mental rotation, which is the process of imagining how the appearance of an object changes orientation when rotated, as described by (Ramful et al., 2016). This inability hinders visualization accuracy, especially in determining the appearance of not directly visible sides. Mental rotation is an important component in understanding the object's structure as a whole, especially when the object needs to be visualized from different perspectives in planning for spatial problem solving.

In addition, the inaccuracy in describing the parts of the stairs, especially the spatial relationship between the left, right, and front sides, shows that the subjects have not fully considered how spatial structures are interrelated in space from various perspectives. This limitation suggests that spatial orientation - the ability to maintain consistency in the shape and position of objects when viewed from different perspectives (Kozhevnikov, 2007)- still needs to be strengthened. Although the subject could identify and calculate the sides of the stairs, the difficulty in maintaining proportions and relationships between parts from other perspectives caused the resulting visual representation to be inaccurate. This impacts the accuracy of the solution strategy developed, because the spatial relationship between geometric elements has not been fully considered dynamically in planning.

Implementing the Plan

At the stage of implementing the plan, the subject made an effort to transform mental representations into pictorial form by trying to draw each side of the stairs based on the plans that had been made previously. However, the resulting drawings still showed discrepancies with the actual shape of the object, especially in maintaining the spatial proportion between the parts of the stairs for motorcycle and pedestrian access. Although the motorcycle access has a larger width in reality, the subject drew it as large as the pedestrian access, reflecting that the spatial visualization process is not yet fully mature. This is in line with the explanation of (Ramful et al., 2016; Turgut & Yilmaz, 2012) Spatial visualization includes the ability to draw and compose visual representations proportional to the actual spatial conditions.

In addition, the subject seemed to understand the necessary mathematical procedures in applying calculations. He could add up the lengths of the sides, divide the sides into appropriate parts, and use the area formula to calculate the total surface that needed to be painted. However, although this calculation was based on logical steps, there was no reflective process on the visual results that had been obtained. The subject did not recheck whether the shape and size in the drawing matched the supposed object, indicating that the internal spatial verification process had not been optimally executed. In fact, according to (Kozhevnikov et al., 2007) Sound spatial reasoning involves the ability to simultaneously interpret and correct spatial relationships in the context of mental visualization and real results.

Furthermore, the subject did not appear to have considered how the appearance of the stairs would change if viewed from a different perspective. The resulting representation is static and does not consider the dynamics of object orientation in space, such as changes in appearance from the side or top. This indicates that spatial orientation ability, which is the ability to imagine how an object will appear when viewed from another angle, has not been developed adequately. Pavlovičováa & Valéria, (2015) This ability is important in maintaining spatial consistency when objects are observed or depicted from multiple perspectives. The inaccuracy in the positioning and proportion of objects in the image shows that the subject is still thinking spatially in a limited framework.

Looking Back Stage

The subject initially attempted to verify the results of the visual representation by matching the drawing with the reference image on the problem sheet. This process shows a form of initial evaluation of the suitability of the representation, which reflects involvement in the spatial visualization process as described by (Ramful et al., 2016), where individuals use visual representations to double-check their cognitive outcomes. However, despite the shape mismatch on the left side and front of the stairs, the subject did not realize the error and stated that the drawing was based on a mental image. This shows that the visual verification process is still superficial, because it does not involve rethinking the spatial structure and the relationship between elements in the object. According to Kozhevnikov et al. (2007), mature spatial reasoning stops at visual matching and includes the correction of spatial mismatches based on an understanding of the real form.

In addition, the subject did not show signs of thoroughly comparing the shape of the mental representation with the actual shape. He did not re-imagine how the object would look if it were rotated or viewed from another angle to ensure the accuracy of the representation. When this mental rotation process is not actively used, examining alternative views also does not occur. Ramful et al. (2016) explain that mental rotation is an important skill that allows individuals to compare mental forms with real forms in the review process. The absence of this process caused the subjects to take their work for granted, without questioning possible orientation errors. This shows that the ability to anticipate and evaluate changes in appearance due to spatial rotation has not been optimally developed in the subject.

Furthermore, when asked about the possibility of other simpler solution strategies, the subject showed no tendency to explore these alternatives and stuck to the initial approach. This shows that the subject does not yet have the flexibility of spatial thinking that allows one to see that a different point of view can produce a more efficient solution. In the context of spatial orientation, (Pavlovičováa & Valéria, 2015) Emphasize the importance of seeing objects from multiple perspectives, not only to understand their shape, but also to evaluate solutions strategically. The subject's inability to see other approaches indicates that his spatial orientation is still rigid and has not developed towards flexible and reflective spatial thinking.

Thus, despite the initiative to review the work, the subject had not yet demonstrated a thorough integration of the three key spatial abilities-visual verification, mental rotation, and exploration of alternative perspectives-which are necessary to build a mature and practical spatial evaluation.

This study has several limitations that should be acknowledged. The research involved only two subjects, each representing a different cognitive style (FI and FD), which restricts the generalizability of the findings to a broader population. The tasks were limited to three-dimensional geometry problems involving a specific stair-like object, so the results may vary if applied to other types of spatial problems or mathematical contexts. The descriptive qualitative approach focused on the reasoning process without quantitative measurements of spatial reasoning ability. Data collection relied on problem-solving tasks and in-depth interviews, making the interpretation highly dependent on the participants' ability to articulate their thought processes and the researcher's interpretations. External factors such as prior learning experiences, motivation, and instructional quality were not examined, even though they may influence spatial reasoning. These limitations open opportunities for future research to involve a larger and more diverse sample, investigate various problem contexts including STEM-based tasks, and employ mixed-method approaches to integrate qualitative insights with quantitative assessments. Further studies may also consider additional factors such as mathematical ability, creativity, or motivation, and design instructional interventions tailored to students' cognitive styles to enhance spatial reasoning skills more effectively. Spatial visualization includes the ability to draw and compose visual representations that are proportional and in accordance with the actual spatial conditions.

CONCLUSION

The analysis indicates that students with a Field Independent (FI) cognitive style generally demonstrate strong visual representation skills, enabling them to understand geometric shapes and structures and devise solutions based on spatial relationships between object components. They can also accurately translate mental visualizations into drawings and maintain spatial consistency during calculations. However, their mental rotation skills are not yet optimal, and they show limited ability to evaluate solutions from different perspectives or to consider alternative strategies.

Meanwhile, students with a Field Dependent (FD) cognitive style display adequate initial understanding in recognizing geometric objects and identifying their appearances from different viewpoints, and the ability to organize solution steps according to relevant mathematical procedures. Nonetheless, their spatial manipulation skills are still limited, especially in mental rotation and adjusting object orientations dynamically. Their visual representations tend to be inaccurate, and there is minimal internal verification; flexibility in evaluating alternative solutions is lacking. These findings suggest that while FI students excel in structural visualization and strategy formulation, and FD students can follow procedural steps effectively, both groups require further development in spatial flexibility, mental rotation, and critical evaluation of solutions to achieve more comprehensive spatial reasoning.

These results imply that geometry learning should integrate targeted activities to strengthen spatial flexibility, mental rotation, and evaluative skills for both groups. Tasks requiring multiple solution paths and perspective-taking for FI learners can expand strategic adaptability. In contrast, FD learners may benefit from scaffolded visual–spatial exercises, dynamic geometry software, and guided opportunities to verify and refine their solutions. Adapting instructional strategies to cognitive style can enhance overall spatial reasoning and foster a more profound, flexible understanding of geometric concepts.

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