The Role of Spatial Visual Intelligence in the Problem Solving Process of Building Spatial Geometry

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Abstract
Visual-spatial intelligence plays an important role in elementary students' geometry problem-solving abilities, but limited research examines how different levels of spatial intelligence affect cognitive strategies in three-dimensional geometry tasks. This study aims to describe the patterns of cognitive strategies used by students with different levels of spatial intelligence and identify specific visualization difficulties encountered during geometry problem solving. This descriptive qualitative research involved in-depth interviews and classroom observations of three fifth-grade students of SDN Karanganyar 03 who were purposively selected based on the categories of high, medium, and low spatial intelligence, with data analyzed using the Miles and Huberman interactive model supported by thematic coding and triangulation techniques. Results showed students with high spatial intelligence demonstrated structured and reflective problem-solving patterns involving mental imagery, sketching, and systematic reasoning, while medium- and low-level students relied on external models or procedural calculations with minimal spatial representation. Students with low spatial capacity often face difficulties with mental rotation, shape manipulation, and visual ambiguity in three-dimensional geometry assignments. This research provides empirical insights into the dynamics of spatial processing in young learners, offering pedagogical implications for improving geometry learning at the elementary school level.
Keywords: *Visual-Spatial Intelligence, Geometry Problem Solving, Elementary Education, Spatial Reasoning, Qualitative Study*

Abstrak
Kecerdasan visual-spasial memainkan peran penting dalam kemampuan pemecahan masalah geometri siswa SD, namun penelitian terbatas yang mengkaji bagaimana tingkat kecerdasan spasial yang berbeda mempengaruhi strategi kognitif dalam tugas geometri tiga dimensi. Penelitian ini bertujuan menggambarkan pola strategi kognitif yang digunakan siswa dengan tingkat kecerdasan spasial berbeda dan mengidentifikasi kesulitan visualisasi spesifik yang dihadapi selama pemecahan masalah geometri. Penelitian kualitatif deskriptif ini melibatkan wawancara mendalam dan observasi kelas terhadap tiga siswa kelas lima SDN Karanganyar 03 yang dipilih secara purposif berdasarkan kategori kecerdasan spasial tinggi, sedang, dan rendah, dengan data dianalisis menggunakan model interaktif Miles dan Huberman yang didukung pengkodean tematik dan teknik triangulasi. Hasil menunjukkan siswa dengan kecerdasan spasial tinggi mendemonstrasikan pola pemecahan masalah terstruktur dan reflektif yang melibatkan citra mental, sketsa, dan penalaran sistematis, sedangkan siswa tingkat sedang dan rendah mengandalkan model eksternal atau perhitungan prosedural dengan representasi spasial minimal. Siswa dengan kapasitas spasial rendah sering menghadapi kesulitan rotasi mental, manipulasi bentuk, dan ambiguitas visual dalam tugas geometri tiga dimensi. Penelitian ini memberikan wawasan empiris tentang dinamika pemrosesan spasial pada pelajar muda, menawarkan implikasi pedagogis untuk meningkatkan pembelajaran geometri di tingkat sekolah dasar.
Kata kunci: Kecerdasan Visual-Spasial, Pemecahan Masalah Geometri, Pendidikan Dasar, penalaran spasial, Studi Kualitatif

INTRODUCTION

Geometry as a branch of mathematics plays an important role in shaping students' spatial thinking skills from an early age, especially in mathematics learning in elementary school. Students are required to not only be familiar with the forms of spatial construction, but also to be able to manipulate, imagine, and represent them in the mind as part of the problem-solving process. (Van de Walle, 2001) emphasizing that geometry needs to be taught because it can develop visual understanding, practice problem-solving skills, and have relevance in everyday life. At the national level, geometry is one of the subjects with the lowest achievement compared to other mathematics subjects such as arithmetic and algebra (Rusyda & others, 2017)), which shows that the visual aspects of geometry are not yet fully mastered by students.

Visual-spatial intelligence, as described in Howard Gardner's theory of compound intelligence, includes the ability to form mental images, visually rotate objects, and organize information in spatial form (Armstrong, 2013). Previous research has shown that students with visual-spatial intelligence tend to use strategies such as drawing models, creating tables, and developing spatial equations as part of their solutions (Pratiwi & Ekawati, 2019). On the other hand, students with logical-mathematical intelligence rely more on symbolic structures and systematic procedures. However, Pratiwi's research also found that although visual-spatial students can understand shapes, they often ignore descriptive information and focus only on numerical and image aspects. This indicates that even though they have visual advantages, students still need to develop a comprehensive thinking strategy.

Global studies show that spatial skills are an important predictor of successful solving of open mathematics problems (Cakir & others, 2016; Rahbarnia & others, 2014). However, there are still limited studies that explicitly examine how visual-spatial intelligence affects students' thinking patterns in solving three-dimensional geometry problems, especially at the elementary education level. In fact, this ability is key in understanding concepts such as volume, nets, and spatial orientation. The absence of mental visualization can lead students to take a mechanistic approach that relies solely on formulas without understanding the spatial structure of the object in question.

This problem shows that there is a gap between learning approaches that emphasize visual representation and the spatial capacity of students that vary widely. Therefore, understanding how visual-spatial intelligence affects students' thinking processes in solving spatial geometry problems is very important. This study aims to investigate the role of visual-spatial intelligence in the problem-solving process of elementary school students when faced with geometry tasks involving building three-dimensional spaces. This study also aims to describe the patterns of cognitive strategies used by students based on different levels of spatial intelligence, as well as to reveal the specifics of the difficulties they experience in the process of spatial visualization.

METHODS

The researcher uses a descriptive qualitative approach (Creswell, 2013) to examine the role of students' visual-spatial intelligence in the process of solving problems of geometry of building spaces. This approach provides an in-depth and contextual overview of students' thinking strategies and cognitive behaviors in real-life learning situations. The researcher chose this design because the study did not focus on the manipulation of variables, but rather on the description of the natural thinking patterns that emerged during the problem-solving process.

The researcher carried out this research at SD Negeri Karanganyar 03, Weru District, Sukoharjo Regency. The researcher assigned three grade VI students as research subjects based on the results of the compound intelligence assessment and the results of initial observation during mathematics learning. The researcher used a purposive sampling technique to select subjects that represented three categories of visual-spatial intelligence, namely high (S1), medium (S2), and low (S3). This selection allows the exploration of different thinking strategies based on variations in students' cognitive profiles.

The researcher collected data through in-depth interviews, direct observation, and documentation of student work. The researcher prepared an interview guide based on four main indicators, namely the ability to visualize geometric shapes mentally, spatial representation strategies, the stages of thinking in solving problems, and the visualization obstacles experienced by students. The researcher also compiled observation instruments based on the same indicators to record behaviors such as drawing activities, hand gestures, direction of view, and verbal expression when facing spatial-based problems.

The researcher compiled an instrument based on a grid that had been validated by two experts in the field of mathematics education and cognitive psychology. The researchers included sample interview questions such as, "What did you imagine when you first read this question?" to explore students' mental picture of building space. The researcher also looked at behaviors such as students' efforts in sketching, explaining shape orientation, or showing doubt as observational data. The research instruments can be seen in Table 1. And 2.

Table 1. Interview Instrument Grid

Yes	Indicators	Main Questions	Purpose of Information Excavated
1.	Mental visualization of building space	What did you imagine when you first read this question?	Knowing the ability to form mental representations
2.	Spatial strategies in solving problems	How do you solve this problem? Do you imagine the shape?	Exploring spatial thinking strategies and initial steps
3.	Problem-solving thinking process	What steps did you take to get the answer?	Knowing the sequence of strategies in solving problems
4.	Visual-spatial difficulties experienced	Which part did you find most difficult when working on this problem? Why?	Uncovering obstacles in the process of spatial visualization

Table 2. Observation Instrument Grid

Yes	Activity Indicators	Observed Behavior	Observation Objectives
1.	Use of visual sketches/geometry	Students make drawings/sketches while reading questions	Observing the form of visual aid used
2.	Representation of mental rotation	Students are seen imagining, twisting, or pointing to shapes by hand	Assess mental rotation ability
3.	Response to visual information	Students understand or experience confusion when looking at a picture of a space building	Identifying initial visual-spatial understanding
4.	Expression of difficulty or confusion	Students show confusion, prolonged silence, or re-ask questions	Observe moments of spatial difficulty during troubleshooting

Researchers analyzed the data using Miles and Huberman's interactive model (Miles et al., 2020) which consists of three stages: data reduction, data presentation, and conclusion drawn. The researcher encoded interview transcripts and observation notes thematically to identify spatial thinking patterns and problem-solving strategies. The researcher maintains the validity of the data through triangulation between sources and member checking on the interpretations that have been made. The researcher obtains ethical approval from the relevant parties and ensures that all participants give written consent and that their identities are kept strictly confidential throughout the research process.

RESULTS AND DISCUSSION

Stages of Geometric Problem Solving

Elementary school students show different stages of thinking in solving geometry problems in building spaces, depending on the level of visual-spatial intelligence they have. The researchers identified that these stages reflect typical cognitive patterns and are important indicators in assessing mathematical problem-solving abilities visually.

Students in the category of high visual-spatial intelligence begin the process of solving problems by reading carefully and then imagining the shape of the building space in question. This student said that he *"first imagined the shape, then drawn, and then calculated."* This statement shows that mental representation becomes the dominant initial stage before students engage with real forms through sketches. This strategy describes a systematic and spatial understanding-based flow of thinking.

Students in the category are carrying out different stages. This student reads the question and immediately looks for external references, such as examples given by the teacher or a friend's answer. The student said *"I look at the example first, continue to follow the way."* This pattern confirms that the student's stages of thinking are still dependent on external stimuli and have not shown the ability to manage spatial information independently. His thought process is built through imitation, not the initiation of personal strategy.

Low-category students show the simplest stages and tend to be in a hurry. The student stated that he immediately looked for the numbers that appeared in the question and then calculated the result. He said *, "I immediately looked for numbers, just kept calculating."* This stage does not indicate the existence of a process of visualization or spatial reasoning. Students directly use formulas without understanding the geometric context of the shapes presented, so the potential for conceptual errors becomes greater.

The difference in the stages of problem solving shows that visual-spatial intelligence influences the order of thinking and the way students construct solutions. Students with high intelligence form mental shadows first, then manifest them in the form of images and numbers. Meanwhile, students with moderate intelligence follow steps based on available models, and students with low intelligence tend to directly execute calculations without an adequate visualization process.

Table 3. Stages of Geometry Problem Solving Based on Student Profiles

Student Name	Troubleshooting Stages
S1 (High)	Reading → Imagining Shapes → Drawing → Counting
S2 (Medium)	Read → Question See examples → Copy steps → Calculate
S3 (Low)	Read → questions Find numbers → Calculate directly

Table 3. It shows that the geometry problem-solving stage of grade VI students is greatly influenced by the level of visual-spatial intelligence they have. Students with high intelligence (S1) carry out a structured thinking process, starting from understanding the problem, imagining the form mentally, drawing visual representations, to calculating systematically. Students with moderate intelligence (S2) still rely on external models, such as examples from teachers, to then copy the same steps without forming their own visualizations. Meanwhile, students with low intelligence (S3) tend to do calculations directly without the stages of visualization or understanding of shapes, which shows a mechanistic thinking pattern and minimal spatial processing. This interpretation emphasizes that the higher the visual and spatial intelligence of students, the more complete and meaningful the problem-solving stages are carried out.

Strategies Used in Problem Solving

Elementary school students apply a variety of strategies when dealing with geometry problems of building spaces, and these differences in strategies reflect varying visual-spatial abilities. The researchers note that students with high visual-spatial intelligence not only use conceptual approaches but also actively engage in physical and mental representations. This student said that he *"drew first, then looked at the sides one by one,"* while in observation he was seen moving his hands as if turning a shape in the air. This behavior signifies that students are not only using sketches as visual aids, but also mentally performing spatial simulations as part of problem-solving strategies.

Medium-category students exhibit strategies that rely more on external visual examples. This student said *"I'm just following the example on the board,"* which shows that his thought process is imitative. In observation, students are seen making simple drawings based on examples and occasionally nodding while processing shapes, although they still seem hesitant. This strategy indicates that the student is not yet fully able to form an internal representation, but is beginning to develop spatial intuition from the available stimulus.

Students with low visual-spatial intelligence use procedural strategies that do not involve explicit understanding of shapes. This student said *"I just use the formula, because I have memorized it,"* which reflects a mechanistic approach without the support of visualization. Observations show that students don't draw pictures, just write numbers, and are silent when asked to explain directions or shapes. This strategy shows a weak spatial involvement, which can have an impact on a low conceptual understanding of geometry.

These strategies show that the higher a student's visual-spatial ability, the more likely they are to use visual aids and mental rotation in solving geometry problems. The combination of mental representation and concrete action is key in effective problem-solving strategies at the elementary school level.

Table 4. Problem-Solving Strategies Based on Interviews and Observations

Student Name	Problem-Solving Strategies	Sketches/Drawings	Mental Rotation
S1 (High)	Draw a sketch and then compare the sides one by one	Create your own drawings and caption sides	Moving your hands like twisting and waking up in the air
S2 (Medium)	Follow the example steps on the board	Create a simple image based on an example	Nodding as if following the form, but hesitating

Student Name	Problem-Solving Strategies	Sketches/Drawings	Mental Rotation
S3 (Low)	Instantly try out formulas without imagining shapes	Don't make pictures, just write numbers	Be silent or confused when asked for the direction of the shape

Obstacles in the Spatial Visualization Process

Elementary school students face various obstacles in the spatial visualization process when solving geometry problems to build spaces. These obstacles appear in various forms, ranging from difficulty imagining a whole form, inability to mentally rotate objects, to doubts in determining the hidden side or part of a building. The researchers noted that the level of resistance experienced by students was closely correlated with the visual-spatial capacity that each individual had.

Students with high visual-spatial intelligence still have difficulties despite having a systematic thinking strategy. The student said that he *was "sometimes confused about the back of the picture,"* and when observing he was seen repeating the image when the shape depicted didn't feel right. This barrier suggests that although students are able to form mental representations, the process is not always stable or precise. When the shape is not fully drawn in the mind, students show a response in the form of a sketch revision as a form of compensation.

Students with intelligence are having difficulty identifying parts that are not directly visible. This student said, *"I have a hard time imagining the invisible side,"* and tends to ask questions to teachers or look at friends when faced with confusion. During observation, students seem hesitant when deciding on the number of sides or the location of certain angles. This obstacle shows that students are not yet able to fully rotate or mentally manipulate objects, so spatial representation is still limited to the visual display available on the surface of the problem.

Students with low visual-spatial intelligence experience the most significant obstacles, both in the process of imagining shapes and in understanding the direction and orientation of the building. This student said that he *"didn't understand the direction, the shape was confusing,"* and during the observation he seemed to be silent for a long time and did not do any visual activities. The inability of students to form a spatial picture causes the thinking process to be interrupted, and the strategies taken tend to be original or only based on the memorization of formulas.

These obstacles show that spatial visualization capabilities are an important aspect of successful geometry problem solving. Students who are able to mentally manipulate shapes tend to have better control over spatial information, while students who lack this ability will have difficulty understanding and solving problems conceptually.

Table 5. Barriers to Spatial Visualization Based on Interviews and Observations

Student Name	Interview Barriers	Expression of Difficulty When Observing
S1 (High)	Confused to imagine the back of the building	Repeat images when they don't fit
S2 (Medium)	Difficult to pinpoint the invisible side	Ask the teacher, look at a friend before answering
S3 (Low)	Not understanding the direction and shape when the question is picture-based	Silent for a long time, looking confused and not drawing at all

Discussion

This study shows that visual-spatial intelligence plays an important role in shaping students' thinking patterns and strategies when solving spatial geometry problems. These findings reinforce the view (Gardner, 2006) in the theory of Multiple Intelligences that visual-spatial intelligence is closely related to the individual's ability to imagine, manipulate, and transform visual forms in space. Students who have high visual-spatial intelligence tend to exhibit a structured, systematic, and mental visualization-based thought process(Mathewson, 1999; Zhou et al., 2022). This can be seen from the stages of problem solving which start from imagining shapes, making sketches, to completing calculations precisely. These findings are in line with the study (Lohman, 1996) which states that visualization ability contributes directly to success in spatial tasks such as geometry.

Students with moderate intelligence exhibit thought processes that are still dependent on external stimuli, such as teacher examples or available images. This dependence reflects the development of spatial representations that are not yet fully mature. Although these students are beginning to form spatial understanding, they still need explicit visual support. This reflects the transition stage in the development of spatial abilities, where students are not yet able to perform complete mental manipulation but begin to build geometric intuition.

Meanwhile, students with low visual-spatial intelligence exhibit thinking patterns that are procedural and mechanistic. They tend to use formulas directly without understanding the context of the geometric shape being worked on. The absence of spatial representation in the thought process indicates a weak ability to form mental images, mentally rotate objects, and connect the properties of spatial construction with conceptual meaning. These findings are in line with the view (Rittle-Johnson & Star, 2007) which mentions that procedural understanding that is not balanced with conceptual understanding can lead to misconceptions in mathematics.

The strategies used by students in solving problems also show a gradation of complexity that is directly related to visual-spatial capacity. Students with high intelligence combine sketches, physical gestures, and mental rotation as a single strategy. Meanwhile, students in the medium and low categories rely on only one or two aspects of the strategy, even in some cases using only the rote approach. This indicates that mental representations and concrete actions (such as drawing and moving hands) are important indicators in effective mathematical problem-solving strategies (Ching & Eroles, 2021; Pourbaix & Soares, 2019).

The spatial visualization barriers found in this study reinforce the importance of spatial-based cognitive training in primary education. Although students with high intelligence still experience confusion when imagining hidden parts of the building, they demonstrate compensatory abilities through image revision or other visual exploration. In contrast, students with low intelligence did not show recovery strategies when faced with obstacles, which signifies weak metacognitive skills in managing spatial learning difficulties.

Overall, this study emphasizes that visual-spatial skills not only affect the success of solving geometry problems, but also determine the depth of the thinking process and the effectiveness of the strategies used. These findings provide important implications for the development of elementary school mathematics curricula that need to make more room for visual exploration, concrete manipulative, and spatial-based learning. Geometry learning is not enough to be given through formulas and practice questions alone, but needs to be designed to stimulate visualization skills, the use of concrete models, and mental rotation and shape transformation exercises.

CONCLUSIONS

Visual-spatial skills form an important foundation in the mathematical thinking process of elementary school students, especially when solving geometry problems to build spaces. Researchers found that the level of visual-spatial intelligence affects the stages of thinking, strategies used, and obstacles faced by students. Students with high intelligence exhibit systematic cognitive processes, characterized by the ability to mentally imagine shapes, draw representative sketches, and calculate based on strong spatial understanding. In contrast, students with moderate and low visual-spatial intelligence tend to use an imitation or procedural approach, which has minimal visualization involvement. These results confirm that internal spatial representations and concrete actions together mediate success in solving geometric problems.

This research provides practical implications for teachers and curriculum designers to integrate spatial visualization reinforcement strategies into mathematics learning in elementary schools. Teachers need to design learning activities that encourage concrete form manipulation, the use of visual models, and gradual mental rotation exercises. The mathematics curriculum needs to be developed to not only emphasize symbolic procedures, but also to practice spatial skills as an integral part of understanding concepts. These findings also open up space for further research exploring spatial-based learning interventions and the development of visual-spatial diagnostic instruments as alternative assessment tools to understand students' cognitive readiness to understand geometry as a whole.

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