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STUDENTS' SPATIAL LITERACY IN GEOMETRIC TRANSFORMATIONS BASED ON VAN HIELE LEVELS OF THINKING

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ABSTRACT

This study aims to describe students' spatial literacy based on the Van Hiele levels of thinking in the topic of geometric transformations among eleventh-grade students at MAN 2 Palu. This research employed a descriptive qualitative approach with three students from class XI C as the subjects, selected based on the results of the Van Hiele thinking level test, each representing the visualization, analysis, and informal deduction levels. Data were analyzed using qualitative data analysis procedures. The findings show that students' spatial literacy varies according to their thinking levels. Students at level 0 (visualization) have fairly good visualization skills but remain weak in reasoning and communication. Students at level 1 (analysis) demonstrate good spatial literacy in terms of visualization and reasoning, although their communication skills are not yet supported by logical justification. Students at level 2 (informal deduction) show strong spatial literacy across all indicators, including visualization, reasoning, and communication. Overall, the results indicate that higher Van Hiele thinking levels correspond to higher spatial literacy in solving geometric transformation problems.

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1) INTRODUCTION

Literacy is a fundamental skill that students must master in an applied manner, particularly in mathematics education, to cope with the rapid digital transformation of the 21st century (Harahap et al., 2022). According to Nugraha & Octavianah, (2020), 19 types of literacy have become the main focus in Indonesia's 21st-century education, including spatial literacy. This form of literacy is increasingly significant as it plays a crucial role in students' ability to understand their environment, solve problems, and construct meaning from visual representations of space.

In the context of mathematics learning, spatial literacy is an essential aspect, particularly in geometry. Spatial literacy involves mental activities such as observation, manipulation, construction, representation, transformation, interpretation, and communication of two- or three-dimensional objects (Mas'udah et al., 2021). These abilities help students to understand geometric concepts while simultaneously enhancing their skills in reading and interacting with their surrounding environment (Ningsih et al., 2021). One of the geometry topics that strongly requires spatial literacy is geometric transformation.

Geometric transformation addresses changes in the position, shape, and size of a figure, including translation, reflection, rotation, and dilation (Pertiwi & Siswono, 2021). These concepts have numerous applications in everyday life, such as object displacement, mechanical movement, and spatial navigation (Azzahra, 2022). As highlighted by Edwards (1997), the study of geometric transformations is crucial for building mathematical understanding, particularly in relation to spatial ability, geometry mastery, and the development of proof competencies. The relevance of spatial literacy in geometry is also reflected in various international assessments, such as the Programme for International Student Assessment (PISA).

According to Lane et al. (2019), PISA is one of the international standards used to assess and evaluate spatial literacy. However, the 2023 PISA results indicate that Indonesian students' mathematical literacy remains low, ranking 73rd out of 79 countries with an average score of 379, far below the OECD average of 489 (OECD, 2023). This low achievement reflects weak conceptual understanding of mathematics, including the spatial literacy required to solve geometry problems. Such conditions highlight the urgent need for further studies on spatial literacy among Indonesian students.

Spatial literacy instruments encompass three interrelated domains: visualization, spatial reasoning, and spatial communication (Moore-Russo et al., 2013). Visualization refers to the ability to form and manipulate mental representations of spatial objects. Spatial reasoning involves the capacity to understand relationships among objects, such as orientation, symmetry, and transformation. Spatial communication, meanwhile, includes the ability to convey ideas, representations, and spatial relationships through language, drawings, symbols, and other forms of representation. These three indicators are highly relevant in the teaching of geometric transformations, which require students to comprehend changes in object positions and relationships among points within a coordinate system. The indicators of spatial literacy proposed by Moore-Russo et al, (2013) are explained in greater detail in Table 1.

On the other hand, Van Hiele's theory provides a systematic framework for understanding the development of students' geometric thinking. This theory outlines five levels of geometric reasoning that students progress through sequentially: visualization, analysis, informal deduction, deduction, and rigor (Yuberta & Firmanti, 2024). Each level can only be attained once the preceding level has been mastered (Musa, 2016). Consequently, identifying students' levels of thinking is crucial for teachers to adjust their instructional strategies in geometry (Idris, 2009). At the senior high school level, studies have shown that students are generally at the visualization, analysis, or informal deduction levels, and have not yet reached the deduction or rigor levels (Razak & Sutrisno, 2017; Wulandari & Ishartono, 2022). The Van Hiele instrument is widely used to identify students' thinking abilities through tasks that require recognition of shapes, understanding of geometric properties, and the ability to provide reasoning for geometric procedures.

Table 1. Indicators of Spatial Literacy According to Moore-Russo

Indicators	Operational Verbs
Visualization	Create sketches of spatial objects through visual drawings based on contextual problems.
Spatial Reasoning	Apply concepts and relationships of spatial objects in calculation techniques.
Communication	Express ideas related to spatial object relationships accurately in written form.

Although numerous studies have examined students' spatial literacy and Van Hiele levels separately, limited research has specifically explored students' spatial literacy profiles based on Van Hiele levels of thinking in the context of geometric transformations at the senior high school level. In particular, empirical studies conducted in Indonesian Islamic senior high schools remain scarce.

Based on the above explanation, the purpose of this study is to describe students' spatial literacy according to Van Hiele's levels of thinking in geometric transformation material among eleventh-grade students at MAN 2 Palu.

2) METHOD

This study employed a descriptive qualitative research design. The descriptive research model was chosen because it aims to provide a comprehensive overview of students' spatial literacy in geometric transformation material as viewed through the lens of Van Hiele's levels of thinking. The qualitative approach was chosen because the study was conducted in a natural classroom context without any instructional intervention.

Three students were selected as research subjects using purposive sampling, each representing a different Van Hiele level of thinking: visualization, analysis, and informal deduction. The selection of the school and class was based on preliminary observations and consultation with the mathematics teacher, indicating that the students had completed instruction on geometric transformations . A total of 31 students were initially given the Van Hiele thinking level test, and the results were analyzed to determine the three students who were selected as the research subjects.

The three selected subjects were then given a test consisting of geometric transformation problems designed based on spatial literacy indicators. Following the test, interviews were conducted to gain a deeper understanding of each student's spatial literacy abilities. The data collected included: (1) the results of the Van Hiele thinking level test administered to all students, which served as the basis for selecting subjects at the visualization level (level 1), analysis level (level 2), and informal deduction level (level 3); (2) the results of the spatial literacy test in the form of the three subjects' responses to geometric transformation problems; and (3) interview data from each subject as supporting information regarding their spatial literacy skills.

The research instruments consisted of: (1) a test for classifying students' levels of geometric thinking, (2) a spatial literacy test, and (3) an interview guide. Data collection was carried out using two methods, namely tests and interviews. To ensure data trustworthiness, time triangulation was employed by administering the tests and conducting interviews twice at different time intervals. If the results of both data collection sessions revealed consistent patterns, the data were considered valid and reliable (Sugiyono, 2013).

The data analysis technique in this study followed the stages of qualitative analysis. First, the results of the geometric thinking level test were compiled and categorized according to the Van Hiele levels to determine the research subjects. Subsequently, the analysis was carried out by referring to the steps outlined by Miles et al, (2014), namely: (1) conducting data reduction on the results of the spatial literacy test and interviews; (2) presenting the data in a structured form; and (3) drawing conclusions based on the overall findings from both the tests and interviews.

3) RESULTS AND DISCUSSION

3.1. Results

1) Subject AI Level 0 (Visualization)

Visualization Indicator

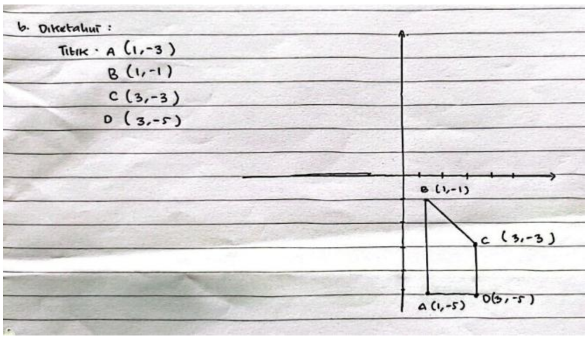

Figure 1. AI's Response to the Visualization Indicator

ased on Figure 1, it can be seen that Subject AI correctly wrote down the information provided in the problem. Furthermore, AI drew a right-angled trapezoid as a representation of the boundary monument in accordance with the vertices given in the problem. To obtain more detailed information, the researcher conducted an interview with AI. The following is an excerpt from the interview transcript with Subject AI.

AIT1 013 P	:	What figure did you imagine in the problem?
AIT1 014 S	:	I imagined a right-angled trapezoid based on the coordinates provided.
AIT1 017 P	:	How did you draw it?
AIT1 018 S	:	I plotted the points according to the coordinates and connected them to form the trapezoid.
AIT1 023 P		Did you find it difficult?
AIT1 024 S	:	No, I could visualize it clearly from the information given.

Subject AI drew a right-angled trapezoid according to the coordinates provided but did not draw the image of the transformed figure.

Reasoning Indicator

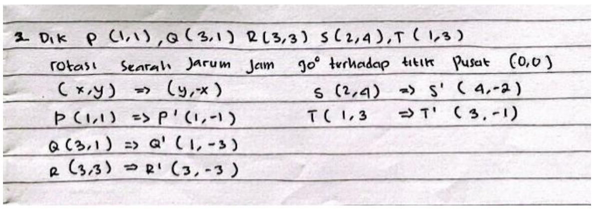

Figure 2. AI's Response to the Reasoning Indicator

Based on Figure 2, it can be seen that Subject AI correctly wrote down the information provided in the problem. Furthermore, AI drew a right-angled trapezoid as a representation of the boundary monument in accordance with the vertices given in the problem. To obtain more detailed information, the researcher conducted an interview with AI. The following is an excerpt from the interview transcript with Subject AI.

AIT1 031 P	:	How did you determine the coordinates of the image points?
AIT1 032 S	:	I applied the 90° counterclockwise rotation formula, $(x, y) \rightarrow (y, -x)$
AIT1 033 P	:	Did you remember it clearly?
AIT1 034 S	:	Not entirely, I just recalled it that way and used it to answer.

Subject AI attempted to determine the coordinates of the rotated figure using a 90° counterclockwise rotation formula but did not obtain the correct result.

Communication Indicator

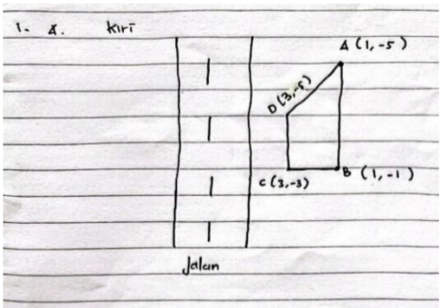

Figure 3. AI's Response to the Communication Indicator

Based on Figure 3, it can be seen that Subject AI did not provide any ideas to answer the problem. AI only drew a road and a right-angled trapezoid on its side in accordance with the information given in the problem. To obtain more detailed information, the researcher conducted an interview with AI. The following is an excerpt from the interview transcript with Subject AI.

AIT1 009 P	:	Do you know what symmetry is?
AIT1 010 S	:	I forgot.
AIT1 015 P	:	What type of transformation did you use?
AIT1 016 S	:	I don't know, the problem was difficult.
AIT1 035 P	:	How would you explain this to a friend?
AIT1 036 S	:	I would just give the formula directly.

Subject AI did not provide written ideas to answer the problem and stated that they would only give the formula directly.

2) Subject Level 1 (Analysis)

Based on Figure 4, it can be seen that Subject RN was able to draw sketches of the plane figure before and after the transformation accurately. To obtain further information, the researcher conducted an interview with RN. The following is an excerpt from the interview transcript with Subject RN.

RNT1 089 P	:	How did you imagine the figure?
RNT1 090 S	:	I imagined it reflected across the Y-axis, with the same shape and size but a different position.
RNT1 097 P	:	How did you draw it?

Visualization Indicator

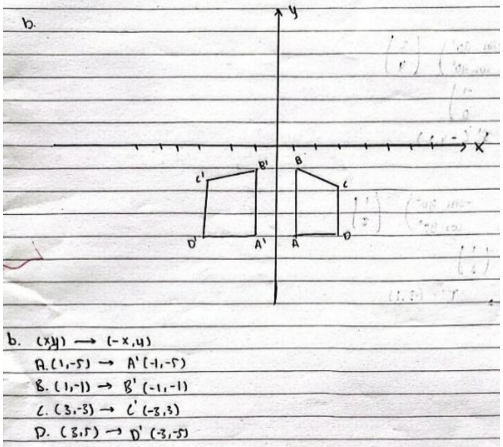

Figure 4. RN's Response to the Visualization Indicator

RNT1 098 S	:	I plotted the points on the Cartesian plane and reflected them to form the figure.
RNT1 101 P	:	Did you find it difficult?
RNT1 102 S	:	A little, especially in determining the coordinates.

Subject RN drew a right-angled trapezoid and its reflection across the Y-axis. The student mentioned experiencing some difficulty in determining the coordinates.

Reasoning Indicator

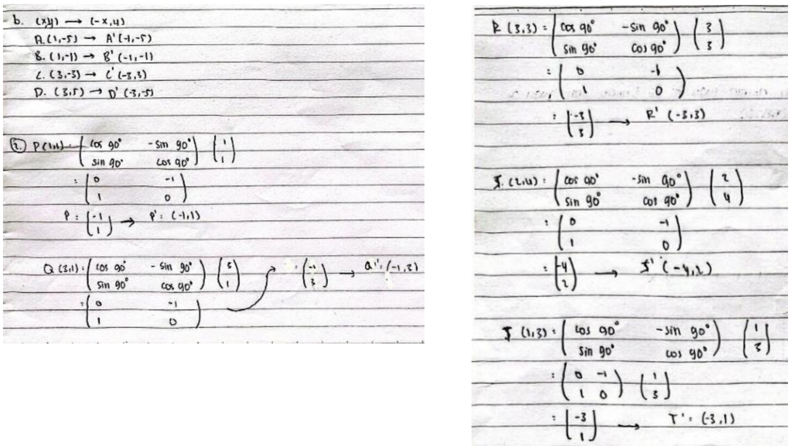

Figure 5. RN's Response to the Reasoning Indicator

Based on Figure 5, it can be seen that Subject RN applied the concept of reflection correctly in solving question number one, part (b), and used the concept of rotation appropriately in question number two. To obtain further information, the researcher conducted an interview with RN. The following is an excerpt from the interview transcript with Subject RN.

RNT1 103 P : What formula did you use?
RNT1 104 S : I used the reflection formula across the Y-axis, $(x, y) \rightarrow (-x, y)$.
RNT1 107 P : How did you determine the rotated coordinates?
RNT1 108 S : I applied the 90° counterclockwise rotation formula, $(x', y') = \begin{pmatrix} \cos 90° & -\sin 90° \\ \sin 90° & \cos 90° \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$
RNT1 109 P : How did you check correctness?
RNT1 110 S : I recalculated the results to ensure consistency.

Subject RN stated that they used the reflection formula across the Y −axis, $(x, y) \rightarrow (-x, y)$, and also applied the 90° counterclockwise rotation formula, $(x', y') = \begin{pmatrix} \cos 90° & -\sin 90° \\ \sin 90° & \cos 90° \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$. They reported checking the results by recalculating to ensure consistency.

Communication Indicator

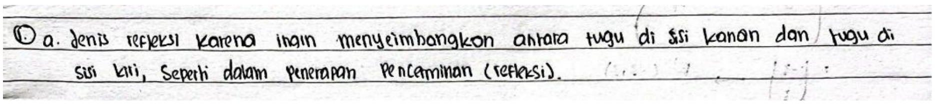

Figure 6. RN's Response to the Communication Indicator

Based on Figure 6, it can be seen that Subject RN had already provided an idea to answer the problem but was not yet able to give an appropriate justification for the choice. RN was unable to provide a mathematical reason. To obtain further information, the researcher conducted an interview with RN. The following is an excerpt from the interview transcript with Subject RN.

RNT1 091 P : What transformation did you use?
RNT1 092 S : Reflection across the Y-axis.
RNT1 093 P : Why did you choose reflection?
RNT1 094 S : To balance the monument on both sides of the road.
RNT1 097 P : How did you solve it?
RNT1 098 S : I used the formula and calculated the coordinates.
RNT1 113 P : How would you explain it to a friend?
RNT1 114 S : I would simply show the formula.

Subject RN explained that symmetry means two figures with the same shape and size after a transformation. They stated that they used reflection across the Y-axis to balance the monument on both sides of the road. When asked how they would explain the solution to a friend, they said they would simply show the formula.

3) Subject Level 2 (Informal Deduction)

Visualization Indicator

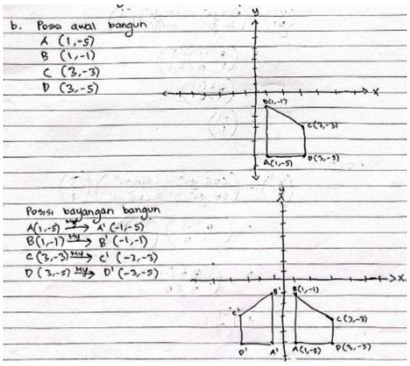

Figure 7. AW's Response to the Visualization Indicator

Based on Figure 7, it can be seen that Subject AW was able to sketch the geometric figure both before and after the transformation accurately. AW distinguished between the figure prior to and after the transformation in order to make the differences and the movement of the figure clearer. To obtain further information, the researcher conducted an interview with RN. The following is an excerpt from the interview transcript with Subject AW.

AWT1 173 P	:	How did you imagine the figure before and after transformation?
AWT1 174 S	:	I imagined a right trapezoid reflected across the Y-axis, with the same shape and size but a different position.
AWT1 177 P	:	How did you draw it?
AWT1 178 S	:	I plotted the coordinates, connected them to form a trapezoid, and then reflected the points across the Y-axis to obtain another trapezoid.
AWT1 183 P	:	Did you find it difficult?
AWT1 184 S	:	A little, especially in determining the position of the reflected points. Once I placed the coordinates, it became easier to draw the image and observe the transformation pattern.

Subject AW sketched the trapezoid before and after reflection across the Y-axis, based on the given coordinates.

Reasoning Indicator

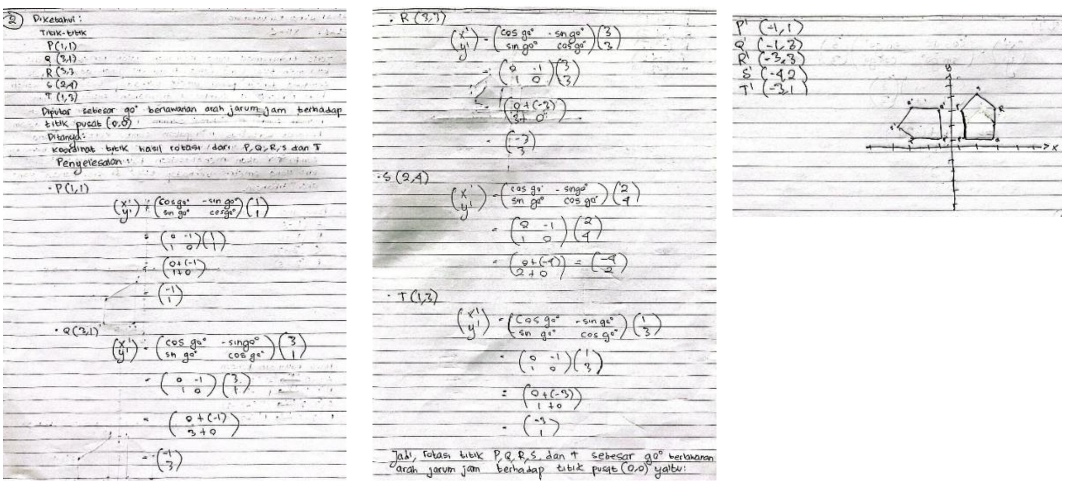

Figure 8. AW's Response to the Reasoning Indicator

Based on Figure 8, it can be seen that Subject AW applied the concept of reflection correctly in solving question number one, part (b), and used the concept of rotation appropriately in question number two. To obtain further information, the researcher conducted an interview with AW. The following is an excerpt from the interview transcript with Subject AW.

AWT1 179 P : What formula did you use?
AWT1 180 S : I used the reflection formula across the Y-axis, $(x, y) \xrightarrow{My} (-x, y)$.
AWT1 191 P : How did you determine the rotated coordinates?
AWT1 192 S : I appliede the 90° counterclockwise rotation formula, $(x', y') = \begin{pmatrix} \cos 90° & -\sin 90° \\ \sin 90° & \cos 90° \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$.
AWT1 193 P : How did you check correctness?
AWT1 194 S : I recalculated and plotted the points to ensure the result was consistent.

Subject AW applied the reflection formula across the Y-axis and used a 90° counterclockwise rotation formula to determine the image coordinates.

Communication Indicator

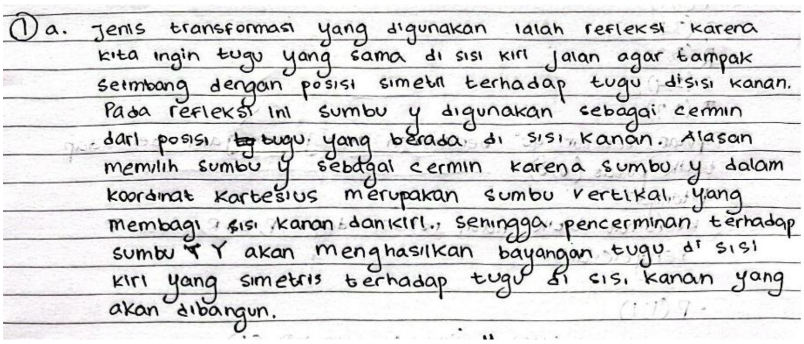

Figure 9. AW's Response to the Communication Indicator

Based on Figure 9, it can be seen that Subject AW provided an idea to answer the problem and was able to give a clear justification for his choice. The reasoning he presented included properties of symmetry, which he expressed in written form. To obtain further information, the researcher conducted an interview with AW. The following is an excerpt from the interview transcript with Subject AW.

AWT1 165 P : What transformation did you use?
AWT1 166 S : Reflection across the Y-axis.
AWT1 167 P : Why did you choose reflection?
AWT1 168 S : To balance the monument on both sides of the road.
AWT1 177 P : How did you solve it?
AWT1 178 S : I used the formula and calculated the coordinates.
AWT1 197 P : How would you explain it to a friend?
AWT1 198 S : I would show both the formula and the figure, so they could see the reasoning and the result clearly.

Subject AW identified the transformation as reflection across the Y-axis, explained the reason, and described the solution using both formula and figure.

3.2. Discussion

1) Spatial Literacy of Subject Level 0 (Visualization)

The analysis shows that Subject AI only fulfilled one spatial literacy indicator, namely visualization. AI was able to draw a right trapezoid on the Cartesian plane correctly, although he did not draw the result of the transformation. AI also admitted that he did not know the type of transformation used. This finding is consistent with (Pebruariska A, 2018), who stated that students at Level 0 are only able to recognize shapes without being able to plan a solution or provide mathematical reasoning. Thus, AI's visualization in the topic of geometric transformations can be categorized as fairly good.

On the reasoning indicator, AI applied the formula incorrectly by using a self-constructed rule. This error aligns with the characteristics of Level 0 students, who recognize shapes without understanding their properties or relationships among objects (Masitoh, 2019). Azzahra, (2022) also found that students at this level struggle to establish procedures, connect transformation concepts, and carry out calculations. Therefore, AI's reasoning is categorized as weak.

On the communication indicator, AI was unable to explain the type of transformation or provide mathematical reasoning. His answers were simple and based only on what was visually apparent. This finding is consistent with Fikria et al, (2023), who stated that students at Level 0 tend to only write down answers without coherent explanation and experience difficulties in expressing ideas. Thus, AI's communication ability in the topic of geometric transformations is also categorized as weak.

This study contributes to the discourse on spatial literacy by confirming that at Van Hiele Level 0, students' spatial literacy is restricted to visualization. They can recognize and reproduce shapes but cannot yet apply properties, procedures, or provide reasoning. This extends spatial literacy research into the context of geometric transformations, highlighting the gap between visual recognition and mathematical explanation.

Instruction for Level 0 students should emphasize recognition of shapes and guided visualization activities. Teachers can use concrete visual aids (manipulatives, dynamic geometry software) and simple transformation tasks to strengthen recognition. Structured prompts and verbal scaffolding can help students begin to articulate spatial ideas, preparing them to progress toward analytical reasoning.

2) Spatial Literacy of Subject Level 1 (Analysis)

The results of the test and interview showed that Subject RN fulfilled two spatial literacy indicators, namely visualization and reasoning. On the visualization indicator, RN was able to draw the figure before and after the transformation accurately and understood the change in its orientation. This ability is consistent with Musa (2016), who stated that students at the analysis level are already able to view figures in a more structured manner.

On the reasoning indicator, RN was able to correctly apply transformation concepts such as rotation, although his reasoning remained procedural and did not yet demonstrate strong conceptual argumentation. This finding is consistent with Wulandari & Ishartono, (2022), who reported that high school students generally remain at the analysis level, where their understanding tends to be procedural.

On the communication indicator, RN was able to mention the type of transformation used but was not able to provide clear mathematical justification. This finding is consistent with Razak & Sutrisno, (2017), who stated that students at the analysis level often produce correct answers but struggle to explain the relationships among concepts coherently.

This finding illustrates that spatial literacy at Van Hiele Level 1 includes visualization and procedural reasoning but limited communication. Students begin to analyze figures and apply transformation formulas correctly, yet their reasoning remains procedural rather than conceptual. This contributes to spatial literacy research by showing how reasoning emerges at this level but is not yet accompanied by coherent communication.

Instruction for Level 1 students should focus on strengthening reasoning beyond procedural application. Teachers can encourage students to justify their use of formulas and explain transformations verbally or in writing. Activities that require students to compare procedures and outcomes can help them develop communication skills alongside reasoning.

3) Spatial Literacy of Subject Level 2 (Informal Deduction)

The analysis shows that Subject AW fulfilled all spatial literacy indicators: visualization, reasoning, and communication. On the visualization indicator, AW was able to draw the figure before and after the transformation accurately and understood the changes in the position and orientation of the object. This finding is consistent with Mas'udah et al, (2021), who stated that spatial literacy includes the ability to manipulate visual representations accurately.

On the reasoning indicator, AW was able to connect the concept of transformation with the calculation steps and provide appropriate mathematical justification. This finding is consistent with Azzahra, (2022), who stated that students with good spatial literacy are able to understand spatial changes and relate them to mathematical concepts in a structured manner. AW's reasoning is also consistent with the characteristics of students at the informal deduction stage.

On the communication indicator, AW was able to convey ideas, reasoning, and solution steps clearly, coherently, and logically. This finding is consistent with Fikria et al, (2023), who explained that students with high spatial communication skills are able to express relationships among spatial objects effectively. Thus, AW's communication ability is categorized as very good and reflects the characteristics of the informal deduction level.

This study confirms that at Van Hiele Level 2, spatial literacy integrates visualization, reasoning, and communication coherently. Students can connect properties of figures with logical reasoning and provide justification for their solutions. This contributes to the theoretical framework by demonstrating that spatial literacy at this level reflects informal deduction, where reasoning and communication are fully developed in the context of geometric transformations.

Instruction for Level 2 students should emphasize tasks that require logical reasoning and structured communication. Teachers can design activities that involve explaining solutions to peers, presenting arguments, or solving problems collaboratively. Such tasks reinforce both reasoning and communication, consolidating spatial literacy at the informal deduction stage.

The comparison across the three subjects shows a clear developmental progression of spatial literacy indicators in line with Van Hiele's levels. At Level 0 (AI), spatial literacy is restricted to visualization, with students able to recognize and reproduce shapes but unable to apply procedures or communicate reasoning. At Level 1 (RN), spatial literacy expands to include procedural reasoning, as students begin to apply transformation formulas correctly, though their communication remains limited and explanations are largely procedural. At Level 2 (AW), spatial literacy reaches integration, where visualization, reasoning, and communication are coherently combined; students not only apply procedures but also justify their choices and articulate solutions clearly. This progression illustrates how spatial literacy develops hierarchically: visualization emerges first, reasoning follows in procedural form, and finally communication integrates with reasoning at the informal deduction stage.

CONCLUSION

Based on the results of the study, it can be concluded that students' spatial literacy abilities in solving geometric transformation problems vary according to their Van Hiele levels of thinking.

1. Students at Level 0 (Visualization) demonstrated good ability on the visualization indicator but remained weak in reasoning and communication. At this level, students tend to perceive shapes only as whole figures without understanding their properties or the relationships among spatial objects. This limitation makes it difficult for them to explain ideas in written form or to determine the correct procedures for geometric transformations.
2. Students at Level 1 (Analysis) demonstrated good ability on the visualization and reasoning indicators. They were able to recognize the properties of geometric figures and apply simple transformations. On the communication indicator, students were able to express ideas, but these were not accompanied by clear and logical reasoning. This shows that their ability to connect spatial concepts with verbal explanations still needs to be further developed.
3. Students at Level 2 (Informal Deduction) demonstrated strong spatial literacy across all indicators, namely visualization, reasoning, and communication. At this level, students were able to explain their reasoning, apply transformation concepts accurately, and clearly represent spatial relationships through both sketches and written explanations. This achievement indicates that their conceptual understanding and mathematical communication skills have developed well.

Overall, higher Van Hiele levels are associated with stronger spatial literacy, particularly in students' ability to reason mathematically and communicate spatial ideas in a structured manner.

These findings suggest that geometry instruction should be designed in accordance with students' Van Hiele levels to support the development of spatial literacy, particularly in reasoning and communication.

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