Senior high school student’s visual-spatial intelligence according to van hiele geometric thinking theory

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Abstract. Visual-spatial Intelligence is very helpful for students in studying the science of geometry which is always associated with the abstract concept of a geometry object. This research discusses the visual-Spatial intelligence of Senior high school students based on geometry thinking level according to van Hiele theory. The design of this research was qualitative research which described visual-spatial intelligence students for each level of van Hiele Theory. The result of this study shows that from 60 high school students, 11 students met the level 0, 16 students met level 1, 28 students met level 2, and 5 students met level 3. This indicates that the students in this research reach more levels higher than the previous level. In addition, the results also show that students who high level geometry. The results showed that there were 11 students of level 0 on geometric ability; 5 students or 45% of students have characteristics of Imaging, 4 students or 36% fulfilled the characteristics of conceptualizing, 1 student or 9% of students have the problem-solving characteristics, and none of the students met the characteristics of the pattern seeking. Next result 16 students in level 1 intelligent on geometric ability. 12 students or 75% students fulfilled the characteristics of the Imaging, 11 students or 69% of students fulfilled the characteristics of Conceptualizing, 8 students or 50% of the students fulfilled the problem-solving characteristics, and students who met the characteristic of the pattern-seeking did not exist. The results of the visual-spatial intelligence of 28 level 2 students on geometric ability showed that 24 students or 86% of students fulfilled the characteristics of Imaging, 23 students or 82% of students fulfilled the characteristics of Conceptualizing, 18 students or 64% of students fulfilled the characteristics of problem-solving, and 3 students or 11% of students meet the characteristics of pattern-seeking. The results showed that there were 5 Students of Level 3 on geometric ability; 5 students or 100% of students fulfilled characteristics of imaging, 4 students or 100% fulfilled the characteristics of conceptualizing, 1 student or 80% of students have the problem-solving characteristics, and 1 student or 80% of the students made the characteristics of the pattern seeking.

1. Introduction

Education is one aspect of daily life that plays an important role in someone’s success. The meaning is, not someone in the world who don’t need education. Education becomes the basis or foundation for every human being to survive with a decent life. Because education makes a lot of people know things that can help him survive. Mathematics is one of basic of education is very important for everyone to learn Mathematics since it is a basic knowledge that is used to study other fields. So, there is no reason for someone not to learn Mathematics. It makes Mathematics be a compulsory subject for every student in Indonesia.

The Kind of mathematics is geometry which focuses on forms and objects and is related to daily life. Geometry provides an opportunity for students to stimulate their ways of thinking, critical thinking, and problem-solving, finding differences, generalizing and summarizing the development of student skills [7]. Therefore, Geometry makes students accustomed to think deductively, to strengthen
students' reasoning, and to train students' proofing skills. The facts indicate that there are serious concerns about students' difficulties in studying geometry around the world. It makes students' geometry ability must be improved by some methods related to Geometry. But before we apply it, we should know the student's geometry ability so that we can apply some method. In this research, we will also discuss the visual-spatial ability because it is very important to be learned by students.

2. Theoretical Review

2.1. Van Hiele Theory
Van Hiele is a figure who plays an important role in geometry. When learning geometry, the teacher has to know the level of the student's ability. It is not allowed teaching geometry with instructional materials that are not suitable for students' ability and capacity [8]. Van Hiele's theory classifies the level of understanding geometry as level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor) with the following explanation:

1) Level 0 (visualization)
At this level, students understand the object in general. They recognize a geometric object with their form as a whole.
2) Level 1 (analysis)
At this level, students begin to analyze the geometric and geometric properties of the naming nomenclature. They do not see the relationship between traits, they think all the traits that are important to solve a geometry problem.
3) Level 2 (informal deduction)
At this level, students or students understand the relationship of natures object. They make definition with their language.
4) Level 3 (deduction)
At this level, students can give evidence of each geometric statement. They are able to understand the implicit nature of an object geometry.
5) Level 4 (rigor)
At this level, students understand the regulation of Mathematics system. They can use all kinds of evidence. They understand the geometry of Euclid and non-Euclidean. They understand the influence of each geometric element.[3].

Van Hiele's theory has a hierarchical level of thinking model, meaning students who have reached certain levels, absolutely have characteristics at the previous level [4]. In addition, each level of them has its own language, symbols, and relationships to form a thinking [3].

2.2. Visual-Spatial Intelligence
Visual-spatial intelligence refers to the ability to perceive the visual world accurately as in a hunter, a scout, or a guide and make transformations and modifications upon one's initial perceptions as what the architect do [2]. Students with visual-spatial intelligence have the ability to manage what they see into their thought [7]. Furthermore, he added that visual-spatial intelligence deals with how students are able to solve problems from what they see with the help of visual thinking of the object. This intelligence involves sensitivity to the colors, lines, shapes, spaces, and relationships that exist between these elements. Moreover, it also covers the ability to visualize, represent visual ideas or visual-spatial graphically, and orientate self them precisely in a visual-spatial matrix.

Proposed Visual-Spatial Intelligence as the ability of perception to recognize physical objects. It is explained that the physical object means a person's sight of the object directly through the sense, not in an abstract way that assessed, the characteristics of the object without seeing it [10]. From these explanations, it is clear that Visual-spatial intelligence is very helpful for students in studying geometry which is related to the abstract concept of a geometry object. Visual-spatial intelligence has four characteristics: imaging, conceptualizing, problem-solving, and pattern-seeking [9].

In this research, will be discussed visual-spatial intelligence based on Geometry Level according to van Hiele Theory. It is a Research novelty because each level of students has different visual-spatial intelligence characteristics.
3. Methodology.

3.1. Participant
The first part of this study was selecting randomly 60 students of Senior High School 1 Glenmore and classifying them based on Van Hiele’s Geometric Thinking Levels using test. The second part of this study was analyzing the visual-spatial intelligence of senior high school students using the test. The final step was to describe the visual-spatial intelligence of senior high school students based on Van Hiele’s Geometric Thinking Levels.

3.2. Design of Research
The purpose of this research is to describe the Visual-spatial intelligence of Senior High School students based on van Hiele’s Geometric Thinking Levels. The design of this research is descriptive qualitative, which describes the Visual-spatial intelligence of Senior High School students based on van Hiele’s Geometric Thinking Levels, it refers to the level of 0 (Visualization), 1 (Analysis), 2 (Informal Deduction), 3 (Deduction), and 4 (Rigor).

![Design of Research Diagram](image)

**Figure 1.** Design of Research

Each level of Geometric Thinking has their own characteristic of students’ ability. This study will discuss the students' visual-spatial intelligence at each level. Visual-spatial intelligence has four
characteristics: imaging, conceptualizing, problem-solving, and pattern-seeking. It will be analyzed based on van Hiele’s Geometric Thinking Levels. Figure 1 is design of research scheme.

3.3. Instrument
In this study data collection was done by the method of test. There were two tests that are used namely the students’ thinking ability test to assessed the Van Hiele Levels and visual-spatial intelligence test. The Hiele’s level of thinking test consisted of 25 questions for 5 levels, which mean there were 5 questions in each level that was validated by 3 geometers. The students who were able to answer at least three questions of each level correctly, they made the criteria of the intended level. The second instrument was a visual-spatial intelligence test. The test consisted of two questions that contain four characteristics of visual-spatial intelligence namely imaging, conceptualization, problem-solving, and pattern seeking. Visual-spatial intelligence test was validated by 3 geometers. The following is one example of the question of level thinking geometry:

From the picture below, it shows that AD, BE, and CF have an allied point. Which one of the following reasons is true?

![Figure 2. Object of Geometry](image)

- a. Only on the picture of the triangle above, we can believe that AD, BE, and CF have an allied point.
- b. On some right triangles, but not all of AD, BE, and CF has an allied point.
- c. On any right triangle, AD, BE, and CF has an allied point.
- d. On any triangle, ADA, BE, and CF have an allied point
- e. On equilateral triangle, AD, BE, and CF have an allied point

3.4. Data Collection and Data Analysis
Data collection in this research in the first part was grouped 60 subjects or students at the level of geometry thinking according to students work. This stage used a validated geometry level thinking test. In the second part, analyzing students' work results at visual-spatial intelligence test according to the geometrical level of thinking. This study will discuss the students' visual-spatial intelligence at each level. Visual-spatial intelligence has four characteristics: imagination, conceptualization, problem-solving, and pattern-seeking. It will be analyzed based on van Hiele's Geometric Thinking Levels.

4. Result and Discussion
Geometry study of the characteristics and structure of an object, shape, and field. In addition, geometry can be used in the study of the entire universe, since all the objects in the universe can be physically studied in form, pattern, and field with geometry. It implies that studying geometry needs understanding from an abstract form to a concrete form or otherwise by utilizing the sense of vision we have. So in studying geometry, it needs a Visual-spatial Intelligence to manage and solve geometry problems correctly. From the definition of Spatial Visual Intelligence, it was knew that Spatial Visual Intelligence requires a high degree of thinking and a very high imagination. Because the visual ability of the spacecraft was not just the ability to imitate, speak or hear only [9].

Previous research in the Czech Republic shows that the level of middle school student thinking is level 2 (informal deduction) [7]. The result of this study shows that from 60 high school students, 11
students met the level 0, 16 students met level 1, 28 students met level 2, and 5 students met level 3. This indicated that the students in this research reach more levels higher than the previous level. So in this research, there were 4 levels of geometric thinking ie Level 0, Level 1 Level, 2, and Level 3.

### Table 1. Percentage of Geometric Ability Level

| No. | Level Geometry of Thinking | Percentage (%) |
|-----|---------------------------|----------------|
| 1   | Level 0 (Visualization)   | 18             |
| 2   | Level 1 (Analysis)        | 27             |
| 3   | Level 2 (Informal Deduction) | 47            |
| 4   | Level 3 (Deduction)       | 8              |

Characteristic of \textit{Imaging} is the ability of students in presenting information and images relevant to problems. Most students at level 0 had trouble in imagining what on their mind. They had difficulties represented the geometric shapes in their imagination into the image form on the answer sheets. But there were some students who could imagine their thoughts in the picture. The next characteristic of visual-spatial intelligence was \textit{conceptualizing}. It deals with a student’s ability to defined the concept of the problem and relate it to prior knowledge. Students at level 0 mostly found it difficult to find geometric concepts related to the shape and character of geometric objects. According to level 0 students, they have difficulty conceptualizing geometry because they understand many concepts but not know the relationship between one concept and another.

Students with good visual-spatial intelligence will be able to accomplish the \textit{problem-solving} form question [9]. The results showed that level 0 students were mostly unable to solved problems by using concepts they understood. It is because students do not meet the characteristics of \textit{conceptualization}. Students did not understand geometry object at the test.

The last characteristic of spatial visual intelligence was \textit{pattern seeking}. This study showed that level 0 students did not meet the characteristics of \textit{pattern-seeking}. According to students, they were very difficult to found the patterns in the arrangement of geometry objects, both numerical and geometric patterns.

Visual-spatial intelligence has four characteristics, namely \textit{imaging}, \textit{conceptualizing}, \textit{problem-solving}, and \textit{pattern-seeking} [9]. The results showed that there were 11 students of level 0 on geometric ability; 5 students or 45% of students fulfilled characteristics of \textit{imaging}, 4 students or 36% fulfilled the characteristics of \textit{conceptualizing}, 1 student or 9% of students fulfilled the \textit{problem-solving} characteristics, and none of the students met the characteristics of the \textit{pattern seeking}. Next is the discussion of visual-spatial 16 students in level 1 intelligent on geometric ability. 12 students or 75% fulfilled the characteristics of the \textit{Imaging}, 11 students or 69% of students fulfilled the characteristics of the \textit{Conceptualizing}, 8 students or 50% of the students fulfilled the \textit{problem-solving} characteristics, and students who met the characteristic of the \textit{pattern-seeking} did not exist. It was because students in level 1 not comprehend concepts of a geometry object. They were only understood a Geometry Object based on the basic form.

Characteristic of \textit{imaging} is about the ability of students in presenting information and images relevant to problems. Most students at level 1 had not troubled in imagining what’s on their mind. They have represented the geometric shapes in their imagination into the image form on the answer sheets. They were could imagine their thoughts difficulties. The next characteristic of visual-spatial intelligence is \textit{conceptualizing}. It deals with a student’s ability to defined the concept of the problem and relate it to prior knowledge. Students at level 1 mostly found it could to found geometric concepts related to the shape and character of geometric objects despite the difficulties.

Students with good visual-spatial intelligence will be able to accomplish the \textit{problem-solving} form question [9]. The results showed that level 1 students were mostly could not solve problems by used
concepts and relationships between concepts they understood. It was because students not understood relationships between concepts.

The last characteristic of spatial visual intelligence is pattern seeking. This study showed that level 1 students did not meet the characteristics of pattern-seeking. According to students, it is very difficult to find the patterns in the arrangement of geometry objects, both numerical and geometric patterns.

The next discussion is about level 2 students on geometric ability according to van Hiele. Theoretically, students at level 2 can make definition use their language. They make meaningful definitions. They are able to provide simple arguments to justify their reasons. They can draw logical maps and diagrams [4]. The results showed that students at level 2 had a good understood of the geometrical form of geometry, distinguishing and naming geometry based on shift and hierarchical sequence. In addition, students can also understand the application by using it. The results of the study on level 2 students indicate the suitability of the van Hiele theory.

The next discussion is level 2 students on geometry ability according to van Hiele. Theoretically, students at level 2 understand the relationship between nature and numbers in geometry. They make meaningful definitions. They are able to provide simple arguments to justify their reasons. They can draw maps and logical diagrams [6]. The results showed that students at level 2 understood well-constructed geometric definitions, they were could differentiate and named geometries that were built on the order of shift and hierarchy. In addition, students could also understand the statement by using it was. The results of the research on the Level 2 students show conformity with the van Hiele theory. The results of the visual-spatial intelligence of 28 level 2 students on geometric ability showed that 24 students or 86% of students fulfilled the characteristics of imagining, 23 students or 82% of students fulfilled the characteristics of conceptualizing, 18 students or 64% of students fulfilled the characteristics of problem-solving, and 3 students or 11% of students met the characteristics of pattern-seeking. Most students at level 2 were could imagine what's on their mind. They represent the geometric shapes that exist in their thinking into the image form on the answer paper. According to level 2 students, it was not difficult to represent their imagination in the form of images.

The next visual-spatial intelligence characteristic was conceptualizing. Students at level 2 largely had not trouble found geometric concepts related to the shape and nature of geometric objects. Theoretically, it was in accordance with the level achieved by students according to van Hiele's theory. Students were could found a connection between two or more concepts of two geometry objects. Students with good visual-spatial intelligence will be able to accomplish the problem-solving form question [9]. The result showed that level 2 students could solve the problem by using the concept and the relationship between the concept of geometry object that they understood, but on the problem-solving characteristic, the students had difficulties. Their difficulty in terms of relationships between concepts on geometric objects.

The last characteristic of visual-spatial intelligence was the pattern seeking. This study showed that level 2 students only 11% can found patterns related to geometry. Students find difficulties in finding the patterns contained in the arrangement of geometry objects. The next discussion is about level 3 students on geometric ability according to van Hiele. Theoretically, students at level 3 understand the relationship between nature and numbers in geometry. Students could provide deductive geometric evidence. They were could distinguish between the necessary and sufficient conditions. At this level, students can give evidence of each geometric statement. They are able to understand the implied traits [5]. The next discussion is level 3 students on the ability of geometry according to van Hiele. Theoretically, students at level 3 understand the relationship between nature and numbers in geometry. Student students can provide deductive geometric evidence. They are able to distinguish between necessary and sufficient conditions. They understand the role of definitions, theorems, axioms, and evidence [5].

Most students at level 3 were could imagine what they had in mind. They easily represented the geometric shapes that exist in their thinking into the image form on the answered paper. According to students at level 3, it was easy to represent their imagination in the form of images. It was could be shown by the following interview below:
Researcher : "Why do you think the tablecloth is square?"

Student : "Because the question provides information stating that the tablecloth is a rectangle which its sides have the same length. Then, because the four ends of the tablecloth should touch the floor, it is clear that the shape must be square because it is related to the same length of diagonal ".

Researcher : "What is the size of the diagonal?"

Student : "The diameter of the table is 1 meter long, the height of the table is one meter. So the diagonal length of the tablecloth is 3 meters".

This is a result of Students work :

![Image](image_url)

**Figure 3.** The result of Students Visual-Spatial Intelligence Test.

D=Diagonal of Square, s=Edges of Square

The next characteristic of spatial visual intelligence is **conceptualizing**. Students at **level 3** mostly found the geometric concepts that were related to the shape and nature of geometric objects. **Level 3** of students used the geometric concepts they found to solved problems related to the conceptual characteristics of visual-spatial intelligence. Students with good visual-spatial intelligence will be able to accomplish the **problem-solving** question [9]. The result of the research shows that level 3 students mostly can easily solve the problem by using concept and relation between geometry object concept which they understand, but on problem-solving characteristic student met difficulties. Their difficulty is in terms of relationships between concepts on geometric objects.

The last characteristic of visual-spatial intelligence is the **pattern seeking**. This study showed that most **level 3** students easily found patterns, both number patterns, and geometric patterns. **Level 3** students also easily work on problems related to the characteristics of **pattern-seeking** in visual-spatial intelligence. Visual-spatial intelligence has four characteristics, namely *imaging, conceptualizing, problem-solving, and pattern-seeking* [9]. The results showed that there were 5 students of **level 3** on geometric ability: 5 students or 100% of students had characteristics of *imaging*, 4 students or 100% fulfilled the characteristics of *conceptualizing*, 1 student or 80% of students had the **problem-solving** characteristics, and 1 student or 80% of the students met the characteristics of the **pattern-seeking**.

This is the student’s problem-solving phase about Visual-Spatial Intelligence Test :

| Code | Visual-Spatial Intelligence Characteristics | The phase of Problem Solving |
|------|---------------------------------------------|-----------------------------|
| 1a   | Imaging                                     | Students write down what is known from the problem. |
| 1b   | Students Imagine the problems               |
| 1c   | Students understand what is the problem asked. |
| 2a   | Conceptualizing                             | Students think about the concept of each geometry object. |

This is a result of Students work :
| Code | Visual-Spatial Intelligence Characteristics | The phase of Problem Solving |
|------|-------------------------------------------|-----------------------------|
| 2b   |                                           | Students Think about the interrelationship between concepts of each geometry object in the test. |
| 2c   |                                           | Students think about the relationship of concept and what is the problem asked at the test. |
| 3a   | Problem-Solving                           | Students think about problem solutions in the test. |
| 3b   |                                           | Students apply the problem solution in the test. |
| 3c   |                                           | Students find problem solution in the test. |
| 4a   | Pattern-Seeking                           | Students think about another solution to the problems. |
| 4b   |                                           | Students find another solution. |

This is the students' portrait phase of Level 0, Level 1, Level 2, and Level 3:

**Figure 4. Students Portrait Phase of Level 0**

**Figure 5. Students Portrait Phase of Level 1**
These are Van Hiele’s Geometric Thinking Levels which indicate that level 0 students (visualization) have a tendency of poor visual-spatial intelligence because they do not meet all the characteristics of visual-spatial intelligence. Level 1 (analysis) students have fair visual-spatial intelligence because they tend to meet only 2 of the four characteristics of visual-spatial intelligence, those are imaging and conceptualizing. Meanwhile, level 2 students (informal deduction) have good spatial visual intelligence, since they fulfill 3 of the four characteristics of visual-spatial intelligence, those are imaging, conceptualizing, and problem-solving. Level 3 students (deduction) have excellent visual-spatial intelligence, as they are able to meet all the characteristics of visual-spatial intelligence. It can be concluded that the higher Hiele’s level can be achieved by the students, the more characteristic of visual-spatial intelligence the students meet.
Table 3. Students Visual-Spatial Intelligence

| No. | Level of Geometry of Thinking | Students' spatial visual intelligence |
|-----|-------------------------------|--------------------------------------|
| 1   | Level 0 (Visualization)       | Very Not Good                        |
| 2   | Level 1 (Analysis)            | Not Good                             |
| 3   | Level 2 (Informal Deduction)  | Good                                 |
| 4   | Level 3 (Deduction)           | Very Good                            |

The results show that the higher the geometric ability of the students, the more spatial visual intelligence characteristics the student possesses. This shows that there is a correlation between the student's geometric ability and the visual intelligence of student spelling. The most characteristic spatial visual intelligence characteristic for a student is the invention of the pattern. Students have difficulty finding patterns in solving problems or solving geometric questions.

5. Conclusion
The higher geometry ability of the high school student in this research was level 0 (Visualization), level 1 (Analysis), level 2 (Informal Deduction), and level 3 (Deduction). The higher the geometric ability of the students caused the students' visual-spatial intelligence was also high.

The visual-spatial intelligence of level 0 and level 1 students were poor, level 2 students have good visual-spatial intelligence and level 3 students have excellent visual-spatial intelligence.

The result of this research shows that geometry ability of students must be improved. Enhancement of students geometry ability can often give the visual-spatial Test or learning based on visual-spatial, especially about Geometry. It will improve Visual-Spatial Intelligence of students and cause the Students Geometry Ability also higher.

The most simple or most widely used by the students is Characteristic spatial visual properties. The most difficult spatial visual intelligence characteristic of a student is the pattern-seeking.

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