Geom

etric Thinking Skills of Seventh Grade Students on the Topic of Triangle and Quadrilateral Based on Van Hiele Geometry Learning Theory

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Abstract. Students’ geometric thinking skills can describe students' understanding of geometrical concepts. According to van Hiele, students' geometric thinking skills is divided into five levels, namely Level 0 Visualization, Level 1 Analysis, Level 2 Informal Deductive, Level 3 Deduction, and Level 4 Rigor. The level of students' geometric thinking skills be an indicator of the success of learning geometry. The teacher should be able to analyse the students' geometric skills to help students to improve their geometric thinking skills. The purpose of this study was to describe the geometric thinking skills of 7th grade students of Junior High School in Boyolali, Indonesia. This type of research was quantitative descriptive research. The study was conducted by giving ten questions that correspond to the level of students' geometric thinking skills. The results showed that as many as 26.09% of students were at level 0, as many as 56.62% of students were at level 1, as many as 17.39% of students were at level 2, and no students were able to reach level 3.

Keywords: Geometric Thinking Skills, Junior High School Students, van Hiele Theory, Triangles and Quadrilateral.

1. Introduction

Geometry is one branch of mathematics that studies objects, points, lines, angles, shapes, spaces, properties, and the interrelated relations between them. Battista (2007) argues, "geometry is a network of concepts, ways of reasoning, and representation systems, which are used to explore and analyze shapes and spaces."

Geometry is one of the materials that must be taught in the school mathematics curriculum, both in elementary schools, junior high schools, and senior high schools. One of the subjects of geometry studied in junior high schools is triangles and quadrilaterals. On the subject of triangles and quadrilateral, students are introduced to various types of triangles and quadrilaterals and their properties, area and circumference of shapes, as well as a quadrilateral, and special lines on the triangle.

Mathematics in schools plays a role in managing reasoning and shaping students' personalities, as well as emphasizing the ability of problems. According to NCTM (2019), learning geometry is studied in schools where students learn to prove the geometry theorem. Students are required to be able to
analyze the properties of geometric shapes and make mathematical arguments about geometric relationships using visualization, spatial reasoning, and geometry modelling to solve problems.

Students' mathematical skills are still low. Proven in the results of the Program for International Student Assessment (PISA) conducted in 2015 for Indonesian junior high school students ranked 63 out of 70 countries in the field of mathematics ability tests. Indonesia obtained a score of 386, with an average score of all 490 countries (OECD, 2016). Based on the Trends in International Mathematics and Science Study (TIMSS) survey in 2011, Indonesia was ranked 38 out of 42 countries in the field of mathematics skills tests. Indonesia obtained a score of 386, with an average score of all participating countries being 500 (Ina V.S. Mullis, 2012). Based on the Junior High School National Examination scores for 2018 Academic Year, the percentage of mastery acquisition of mathematical problems in the "geometry and measurement" material was 42.80% at the National level.

According to Van Hiele's Theory (Usiskin, 1982), there are five phases of learning geometry, namely the information, orientation, exploitation, free orientation, and integration phases. Van Hiele's theory states that the geometric thinking skills has 5 (five) levels, namely: 1) Level 0 Visualization, 2) Level 1 Analysis, 3) Level 2 Informal Deduction, 4) Level 3 Deduction, 5) Level 4 Rigor (Crowley, 1987). At level 0, students recognize geometric shapes. At level 1, students are familiar with the properties of geometry. At level 2, students know the relationship between geometric shapes and other geometric shapes. At level 3, students can draw deductive conclusions, namely conclusions from various things that are specific. At level 4, students understand how important the accuracy of the basic principles underlying proof and understand why something is used as a postulate or proposition (Purwoko, 2019). According to Yildiz (2009) 7th Grade Junior High School was at informal deduction (level 2) of van Hiele’s geometric thinking skills. It means that 7th Grade Students of Junior High School could reach level 0, level 1 and level 2 of van Hiele’s geometric thinking skills and no students could reach the level 3.

The students’ geometric thinking skills can be an indicator of the success of mathematics learning. If the students' geometric thinking skills is high, it means mathematics learning is done well, while students' low geometric thinking skills indicates that the learning of mathematics that took place was less successful. The teacher should be able to help students to improve their geometric thinking skills. The first step that must be done is to analyze the students' geometric thinking skills. For this reason, it is necessary to conduct research on students' geometric thinking skills, as a material for teacher evaluation whether the ongoing geometry learning is going well. This study aims to determine the geometric thinking skills of 7th grade students in junior high school, especially on triangles and quadrilateral material, and describe the facts found in the study.

2. Research Methods

This type of research was quantitative descriptive research. Quantitative descriptive research is one type of research that aims to describe systematically, factually, and accurately about the facts and characteristics of specific populations, or try to describe phenomena in detail (Lehmann, 1979). Quantitative descriptive research is a conscious and systematic effort to provide answers to a problem and/or obtain more in-depth and extensive information on a phenomenon by using stages of research with a quantitative approach (Yusuf, 2014). According to Arikunto (2006), quantitative descriptive research is not intended to test hypotheses, but only describes what they are about a variable. According to Erik (2015), quantitative descriptive research is in the form of numbers and percentages. As for the variable in this study, it was the geometric thinking skills, with the subject of research was 7th grade students of junior high school.

Data collection techniques were carried out by giving written tests to 7th grade students and analyzing students' answers on each item. The test was used to identify how the geometric thinking skills of 7th grade students, especially in the subject of triangles and quadrilateral. The data analysis technique used an interval scale. According to Djaali et al. (2000), an interval scale is a scale that has the same distance between one data with other data. The interval scale is identical to the real number. According to Suryabrata (2003), interval scales are mutually exclusive; the data categories are logical,
the data categories are scaled based on the number of special characteristics they have, the same characteristic differences are reflected in the same difference in the amount imposed on the category, and the zero only represents a point on the scale (it has no absolute zero).

3. Results and Discussion

The test instrument was tested on twenty-three (23) 7th grade students of Junior High School in Boyolali to determine the students' geometric thinking skills on the subject of triangles and quadrilateral. The test questions were in the form of description questions to identify students' geometric understanding. The test instrument used consisted of ten items, with details of three items to test the skills at level 0, two items to test the skills at level 1, four items to test the skills at level 2, and one question to test the skills at level 3, with the grid described in the following table:

| Item Question | Level | Indicator                                                                 | Total Score |
|---------------|-------|---------------------------------------------------------------------------|-------------|
| 1             | 0     | Recognizing and naming a shape based on its general appearance.           | 10          |
| 2             | 0     | Grouping and classifying shapes based on appearance.                      | 10          |
| 3             | 0     | Creating, drawing, or copying a rectangular shape.                        | 10          |
| 4             | 1     | Comparing the two shapes based on the relationship between the elements.  | 15          |
| 5             | 1     | Discovering the specific shape characteristics empirically and making generalizations about the characteristics of a group of shapes. | 15          |
| 6             | 2     | Finding the relationship between the characteristics of shapes.           | 15          |
| 7             | 2     | Finding the minimum properties that can define shapes.                    | 15          |
| 8             | 2     | Seeing that shape is another subgroup of shapes.                           | 15          |
| 9             | 2     | Forming and using the definition of shapes.                               | 15          |
| 10            | 3     | Proving the relationship between theorem and related statements.          | 30          |

Students worked on individual test questions and the test result presented in the following table:

| Subject | Score of Each Question | Total Score |
|---------|------------------------|-------------|
|         | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Level 0 | Level 1 | Level 2 | Level 3 |
| 1       | 7.5 | 8 | 10 | 15 | 12 | 15 | 8 | 0 | 13 | 0 | 25.5 | 27 | 36 | 0 |
| 2       | 8.5 | 9.5 | 10 | 9 | 9 | 12 | 5 | 7 | 5 | 0 | 28 | 18 | 29 | 0 |
| 3       | 8.5 | 8 | 9 | 15 | 6 | 10 | 14 | 6 | 10 | 0 | 25.5 | 21 | 40 | 0 |
| 4       | 8 | 5.5 | 8 | 2.5 | 6 | 15 | 0 | 0 | 0 | 0 | 21.5 | 8.5 | 15 | 0 |
| 5       | 8 | 8.5 | 8 | 10 | 14 | 2 | 10 | 6 | 2 | 0 | 24.5 | 24 | 20 | 0 |
| 6       | 6.5 | 4.5 | 1 | 2 | 9 | 10 | 0 | 0 | 0 | 0 | 12 | 11 | 10 | 0 |
| 7       | 7.5 | 7.5 | 8 | 10 | 9 | 12 | 12 | 6 | 7 | 0 | 23 | 19 | 37 | 0 |
| 8       | 8.5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13.5 | 0 | 0 | 0 |
| 9       | 8 | 8 | 10 | 15 | 15 | 15 | 14 | 7 | 13 | 0 | 26 | 30 | 49 | 0 |
| 10      | 7.5 | 9 | 10 | 12.5 | 12 | 12 | 5 | 6 | 2 | 0 | 26.5 | 24.5 | 25 | 0 |
| 11      | 9 | 8 | 8 | 5 | 6 | 15 | 10 | 3 | 2 | 0 | 25 | 11 | 30 | 0 |
| 12      | 9 | 6 | 8 | 15 | 6 | 15 | 0 | 0 | 0 | 0 | 23 | 21 | 15 | 0 |
After got the total score of every level, then student scores were analyzed using the criteria below:

### Table 3. Assessment Guidelines for Criteria of Geometric Thinking Skills

| Level of Questions | Criteria for Geometric Thinking Skills |
|--------------------|----------------------------------------|
|                    | Very less | Less | Enough | Good | Very good |
| Level 0            | 0 ≤ x ≤ 6 | 6 < x ≤ 12 | 12 < x ≤ 18 | 18 < x ≤ 24 | 24 < x ≤ 30 |
| Level 1            | 0 ≤ x ≤ 6 | 6 < x ≤ 12 | 12 < x ≤ 18 | 18 < x ≤ 24 | 24 < x ≤ 30 |
| Level 2            | 0 ≤ x ≤ 13 | 13 < x ≤ 26 | 26 < x ≤ 39 | 39 < x ≤ 52 | 52 < x ≤ 65 |
| Level 3            | 0 ≤ x ≤ 6 | 6 < x ≤ 12 | 12 < x ≤ 18 | 18 < x ≤ 24 | 24 < x ≤ 30 |

X was the total score obtained at each level of questions.

Students are said to exceed the level of geometric thinking skills if they meet the criteria of "good" or "very good" at each level of the questions. Using the guidelines in Table 2, an analysis of student answers was conducted.

The results of the analysis of students' geometric thinking skills tests are presented in the following table:

### Table 4. Analysis Results of Students Geometric Thinking Skills Tests

| Subject | Passment of Geometric Thinking Skills Level | Conclusion |
|---------|-------------------------------------------|-------------|
|         | Level 0 | Level 1 | Level 2 | Level 3 |
| 1       | Pass    | Pass    | Not Pass | Not Pass | Level 1 |
| 2       | Pass    | Pass    | Not Pass | Not Pass | Level 1 |
| 3       | Pass    | Pass    | Pass     | Not Pass | Level 2 |
| 4       | Pass    | Not Pass| Not Pass | Not Pass | Level 0 |
| 5       | Pass    | Pass    | Not Pass | Not Pass | Level 0 |
| 6       | Not Pass| Not Pass| Not Pass | Not Pass | Level 0 |
| 7       | Pass    | Pass    | Not Pass | Not Pass | Level 1 |
| 8       | Not Pass| Not Pass| Not Pass | Not Pass | Level 0 |
| 9       | Pass    | Pass    | Not Pass | Not Pass | Level 2 |
| 10      | Pass    | Pass    | Not Pass | Not Pass | Level 1 |
| 11      | Pass    | Not Pass| Not Pass | Not Pass | Level 0 |
| 12      | Pass    | Not Pass| Not Pass | Not Pass | Level 1 |
| 13      | Pass    | Not Pass| Not Pass | Not Pass | Level 1 |
Subject | Passment of Geometric Thinking Skills Level | Conclusion
--- | --- | ---
Level 0 | Level 1 | Level 2 | Level 3
--- | --- | --- | ---
14 | Pass | Pass | Not Pass | Not Pass | Level 1
15 | Pass | Not Pass | Not Pass | Not Pass | Level 0
16 | Pass | Pass | Not Pass | Not Pass | Level 1
17 | Pass | Pass | Not Pass | Not Pass | Level 1
18 | Not Pass | Pass | Not Pass | Not Pass | Level 1
19 | Pass | Pass | Pass | Not Pass | Level 2
20 | Not Pass | Not Pass | Not Pass | Not Pass | Level 0
21 | Pass | Pass | Not Pass | Not Pass | Level 1
22 | Pass | Pass | Not Pass | Not Pass | Level 1
23 | Pass | Pass | Pass | Not Pass | Level 2
N = Number of students who pass the level of geometric thinking skills

Based on tests conducted, data obtained that as many as 26.09% of students were at level 0, as many as 56.62% of students were at level 1, as many as 17.39% of students were at level 2, and no student was able to pass level 3. This study gave a completely different result from what Sulistiowati (2018) did to 7th Grade Students of Junior High School in that 75% of students were at level 0, 20% of students were at level 1, 5% of students were at level 2, and no students had been able to reach level 3. On the other hand, Argaswari (2018) studied that 12.50% of students were at level 0, 54.17% of students were at level 1, 33.33% of students were at level 2, no student was able to pass level 3. Although these studies gave different result, they had something in common that no students could reach level 3.

The studies in line with Yildiz (2009) that 7th Grade Junior High School was at informal deduction (level 2) of van Hiele’s geometric thinking skills.

In the next step, each item was analyzed to find out the percentage of students who could answer the item well. Students are said to be able to answer the questions well if at least they can get 60% of the maximum score on each item. Based on these criteria, the following data are obtained:

| Item Question | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------------|---|---|---|---|---|---|---|---|---|----|
| Y (%)         | 100.00 | 78.26 | 82.61 | 73.91 | 91.30 | 82.61 | 39.13 | 0.00 | 30.43 | 0.00 |

| Y = Percentage of students who can answer the item well.

The following is descriptions of students’ answer to each item question. In question number 1, students were asked to give the name of the shape in accordance with the picture. Students' answers showed that most students could recognize and name their shapes based on their appearance with standard names, but some students could not give specific shape names, such as recognizing "trapezoid" shapes but did not know "right trapezoid". The example of student’s answer can be seen in figure 1.
In question number 2, students were asked to group the provided shapes into "groups of rectangular shapes," "groups of triangle shapes," and "groups of not triangle shapes and squares." Students' answers showed that most students could classify shapes of triangles and quadrilaterals whose shapes were familiar, but no student could classify shapes of triangles and unfamiliar quadrilaterals, such as figures numbers 5, 10, and 19. The shapes, which were grouped in questions number 2, can be seen in figure 2 below:

![Figure 2. Shapes on question number 2](image)

In question number 3, students were given the properties of a shape (equilateral triangle), then students were asked to draw a shape in accordance with the properties of the shape. Student answers indicated that students could recognize the intended shape; students could draw equilateral triangles but only rough drawings. Students have not been able to draw an exact equilateral triangle, as shown in figure 3.

![Figure 3. Sample 2 Student Answers](image)
In question number 4, students were asked to explain the difference between square and rectangle. Student answers indicated that some students could identify the difference between square and rectangle, while some students only identified the properties of a square and rectangle. The example of student’s answer can be seen in figure 4.

![Figure 4. Sample 3 Student Answers](image)

In question number 5, students were asked to identify the characteristics of the parallelogram. Student answers showed that most students could identify the characteristics of a parallelogram well, although sometimes students did not use standard vocabulary. The example of student’s answer can be seen in figure 5.

![Figure 5. Sample 4 Student Answers](image)

In question number 6, students were asked to determine the area of KLN and the area of KLMN in figure 6, then find the relationship between the area of KLN and the area of KLMN. Student answers indicated that most students could determine the area of each shape and the relationship between the two, but they could not draw conclusions correctly. The example of student’s answer can be seen in figure 7.

![Figure 6. Picture in Question Number 6](image)
In question number 7, students were asked to determine the minimum characteristic that defines a parallelogram. Most students could not answer correctly, as shown in figure 8 and figure 9.

In question number 8, students were asked to answer the question, "Is the rectangle a square? Is a square a rectangle? Is the rhombus square? Is square a rhombus?" Of the 23 students who worked on the problems, there were no students who could answer well. The example of student’s answer can be seen in figure 10.

In question number 9, students were asked to define an isosceles triangle. Student answers indicated that students had not been able to define an isosceles triangle correctly. Students understood whether it was an isosceles triangle, but they were unable to make a definition of the word “triangle. Some students did not make definitions but a list of the properties of the isosceles triangle. The example of student’s answer can be seen in figure 11.

In question number 10, students were asked to look for relationships of a, b, and c. However, no student could provide the answer requested.
4. Conclusion

The results of the study in 23 7th grade students of Junior High School in Boyolali showed that as many as 26.09% of class students were at level 0, as many as 56.62% of students were at level 1, as many as 17.39% of students were at level 2, and no student was able to reach level 3 thinking skills of geometric van Hiele.

Furthermore, at level 0, 100% of students were able to recognize and name the shapes according to their appearance, 78.26% of students were able to classify their shapes, and 82.61% of students were able to draw a picture. At level 1, as many as 73.91% of students were able to compare two shapes based on the relationship between the elements, and as many as 91.30% of students were able to discover specific shape characteristics empirically and make generalizations about the characteristics of a group of shapes. At level 2, 82.61% of students were able to find the relationship between the properties of the shape, as many as 39.13% of the students found the minimum characteristics that could define the shape, as many as 0.00% of students saw that a shape was another shape subgroup, and as many as 30.43% of students could form a definition of shape. At level 3, none of the students could prove the relationship between theorem and related statements. Data obtained from the study could be used by teacher as assessments for geometry learning the expected teacher to enhance the students’ geometric thinking skills.

5. Suggestion

The results of the study should be used by researchers to be able to develop and apply geometry learning so that students’ geometric thinking skills can be improved. Teachers should be able to evaluate the learning that has been done so that they can apply it to better learning.

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