Van Hiele Thinking Level and Geometry Visual Skill towards Field Dependent-Independent Students in Junior High School

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Abstract. This research aimed to describe the geometry visual skill at level 0 (visualization), level 1 (analysis) and level 2 (ordering) according to Van Hiele Theory towards field independent students in Junior High School. This research was a survey. The research conducted for grade 8 students of Junior High Schools with a range of age between 14 until 15 years old. The samples were selected using proportionate stratified random sampling technique which was a combination of stratified sampling technique and proportional sampling technique followed by random sampling technique. This technique was used to determine the sample proportionately for each strata. The samples consisted of 103 students from 4 representative high strata schools. The data were collected by using tests. Data analysis was done with quantitative and qualitative approach. The result showed that most of students have FD cognitive style. Most of FI students’ score show a better result than FD students’ score in each level of van Hiele. There is not specific pattern to describe students’ visual skills for each van Hiele level. It does not indicate that the higher the level of van Hiele achieved by students, the better the visual skills of students.

1. Introduction

Mathematics is one of field of science which has an important role in life so that it is taught at every education level. Because it is needed at all education level, mathematics becomes a basic of science as its role in science and technology growth [1]. This is confirmed that "It is a remarkable fact that, in almost every country, mathematics occupies a central place in the school curriculum" [2]. Mathematics can be categorized into three branches, namely algebra, geometry, and analysis [3]. In mathematics, geometry is an important branch because it is used by many people and it relates to daily life. This is in line with the statement of [4] that geometry is not only an important part of mathematics but also it is an important part of life. For example, geometric forms can be seen in snow chunks, cobwebs, decomposition in the water, rainbow, buildings, parks, and many others. Then people make many things such as capsules and tablets in the pharmaceutical field, the manufacture of bicycles, motorcycles, cars, and planes, all of them contain mathematical formulas including geometry in it.

Galileo emphasized that in learning mathematics, it is important to understand geometry, because geometry was the key to understand nature, this indicates that how important for students to learn geometry at school [5]. But the fact shows that the students' geometry achievement are still not good enough. Based on the research, the most students have difficulties in learning geometry [6]. This also happened in America which showed that geometry is hard to learn especially about proof [7]. In Indonesia, based on the results of pra-survey which showed that students' geometry understanding was still good enough, students can classify the name of geometry shapes but they can’t mention each
shape and even some of them mention that rectangle as an isosceles rectangle or equilateral rectangle [8]. Research also found that students do not understand the properties of geometry figure well [9]. The similar problem also happened when researcher did observation in schools to know about student’s knowledge about geometry, it showed that students still have difficulties to notice properties of a figure, some of them may know the properties but they are not able to explain it in an exact sentence. Some of students also does not know about diagonal, parallel line and perpendicular line.

The geometry ability of students is still not good enough. Van Hiele level theory can be used as a good descriptor in measuring geometry capabilities because learning is designed on the basis of students' thinking [9]. According to Van Hiele's theory, there are five levels of thinking that students get in understanding geometry, level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor) [10]. [11] stated that students in high school could be at level 0. To find out each student's level, the Van Hiele Geometry Test (VGHT) was compiled in five questions which are created by using the behaviors that have been identified by Van Hiele in his theory. The test contains basic lessons of two dimension figures. Therefore, VGHT can be used for elementary, junior and senior high school students who have obtained the material.

At level 0, students identify figures by their appearance as a whole, but they do not notice its properties. At level 1, students begin to recognize properties of a figure. At level 2, students order definition of figure based on properties and figures to make deduction of relationship between them. At level 3, students are able to construct proof, understand the role of axioms and definitions and provide reasons for every steps in a proof. At level 4, students understand the formal aspects of deduction and they can interrelate different axiomatic systems of proof [12].

In addition, in every level of van Hiele thinking, students should also have basic skills in solving various geometric problems [13]. Hoffer presents five basic geometrical skills that are important for students: visual skills, verbal skill, drawing skills, logical skills, and applied skills[14]. Each student has different skills at each level. In visual skill, he explains that student can recognize different figures from a pictures, notices properties of a figure and also recognize inerrelationships between different types of figures. Visual skill is also connected with spatial and holistic functions. In verbal skill, students have to have a good ability in the use of language. Some students have many difficulties to describe a concept, for example students said that they understand it but they can not say it. Drawing skill provides opportunities for students to reveal their ideas in pictures and diagrams which may through a verbal description. Logical skill requires students to make a conclusion based on certain given information. Students need more experiences to develop their logical skill. In applied skill, students describe phenomena mathematically. This is called mathematical modeling.

Students also need to analyze every geometry problem to solve well. In solving those problems, every student has their own way to find the answer. This could be effected by different cognitive style of each students. It is in line with the view that cognitive style effects students thinking way so it is important fo them to reach geometry level thinking in mathematics learning [15]. One of cognitive style which has the most attention for its educational implications is field dependent (FD) and field independent (FI) [16]. FI students are better than FD students in analysis. FI students prefer work alone, have self-defined goals and most likely to develop their own learning strategies. FD students prefer to learn together in group, need to discuss with teacher or peers with more frequencies, teacher need to guide them as extrinsic reinforcement and direction [17].

It is necessary to describe the characteristics of the students' geometry skills based on the level of van Hiele thinking development in geometry learning and to understand student’s cognitive style so that the teacher can provide the appropriate treatment to improve the geometry skill of the students at their thinking level. It is also necessary to analyze the skills of students' geometry based on the level of Van Hiele thinking development. In this study, it will be analyzed the schools in high stratified. It will be seen how students' geometry skills at each van Hiele thinking level towards field dependent-independent students in high-stratified schools.
2. Methods
This study was a survey. The population in this study was 8th grades with age range 14 – 15 from 36 schools. Sampling technique uses stratified proportional random sampling. School groupings are based on math score of the national examination on 2016/2017 academic year. There were four high-stratified schools and it took a class in every school for sample.

Data collection techniques used tests and interviews. The test instruments in this study were Group Embedded Figures Test (GEFT), Van Hiele Geometry Test (VGHT) and geometry visual skill test. The GEFT has been developed by Oltman, Raskin and Witkin (1971) to assess field dependent-independent student [18]. There are three section with 25 complex figures in this test, and it took 15 minutes to finish the test. Students are FD group if GEFT scores is in range 0-11, and if GEFT scores above 11, students are FI group [19, 20].

VGHT was developed by The Cognitive Development and Achievement in Secondary Geometry Projects (CDASSG). VGHT is designed to measure students’ thinking level in geometry. The test consists 15 multiple choices questions. Each level is represented by five questions and it took 20 minutes to do the test. Students can be at a certain level if they can answer three questions correctly.

Furthermore, it will be given a matter of geometry skills test according to Hoffer. The test consists 1 essay visual skill question. It consists of 5 questions to measure 3 indicators in visual skills: (1) recognizing different figures from a picture, (2) noticing properties of a figure, and (3) recognizing interrelationships between different types of figures. Each indicator is represented in question a, b and c. It needs 15 minutes to do the test. In this study, interview was used unstructured interview according to developed interview guidelines. Procedure of the study started from giving GEFT to four classes to know cognitive style of students to become field dependent-independent students group. Furthermore, students answered VGHT to measure students' thinking level in geometry, and the last test was to answer geometry visual skill to know students’ visual geometry.

3. Result and Discussion

| School | CS | Van Hiele Level | n FD | n FI |
|--------|----|-----------------|------|------|
| A      | FD | 13              | 13   |      |
|        | FI | 12              | 2    | 1    |
| B      | FD | 8               | 14   |      |
|        | FI | 10              | 5    | 1    |
| C      | FD | 14              | 18   |      |
|        | FI | 2               |      | 3    |
| D      | FD | 15              | 15   |      |
|        | FI | 6               | 9    |      |
| Number |    | 80              | 60   | 43   |
| Percentage | 77.67 | 19.42 | 2.91 | 58.25 | 41.75 |

Table 1 shows that the number of FD students is more than the number of FI students. It means that most of students have FD cognitive style. FD students at school A and school D only can achieve level 0. The smallest amount of FI students is at school C. There are only two FI students. There are three students at level 2, two of them are FI, and one is FD. Only school C which can not achieve level 2. Overall, most of students are in level 0 with percentage of 77.67. This is in line with the argue that that students in high school could be at level 0 [11].
Table 2. Visual Geometry Test Result

| CS | VHL | a | X max a | b | X max b | c | X max c |
|----|-----|---|---------|---|---------|---|---------|
| 0  | 1.64| 2 | 1.39    | 4 | 0.63    | 2 |
| FD | 1.59| 2 | 2.5     | 4 | 0.78    | 2 |
|    | 2   | 2 | 0       | 4 | 0      | 2 |
| 0  | 1.77| 2 | 2.05    | 4 | 0.83    | 2 |
| FI | 1.91| 2 | 2.32    | 4 | 0.82    | 2 |
|    | 2   | 1.83| 2,13   | 4 | 0.50    | 2 |

Table 2 explains that most of FI students’ score show a better result than FD students’ score in each level of van Hiele. It is appropriate with [21] that states FI students is better in mathematics and science than field dependent students. Only FD students at level 1 have better result to notice properties of a figure and FD students at level 2 have better result to recognize different figures from a picture. It could because some FI students did not answer carefully and some of their answer was totally wrong, so it makes the average value is below FD students’ average value. The average value of the right answer of FD student at level 2 at question b and c is 0 because there is just one student in that level and she did not answer question b and c. The average value of FD and FI at question b does not approach to 4 because most of FD and FI student did not answer completely or they answer completely but most of their answer is incorrect.

On Table 2, a, b, and c are questions which respectively to measure visual skill students to recognize different figures from a picture, to notice properties of a figure, and to recognize interrelationships between different types of figures. Question a, b and c on Table 2 also represent the average value of students answer and the maximum average value of right answer. Overall, it can be seen that there is not specific pattern to describe students' visual skills for each van Hiele level. It does not indicate that the higher the level of van Hiele achieved by students, the better the visual skills of students. These following figures are presented some students’ answer of FD and FI.

![Figure 1. Question a, b and c.](image-url)
Figure 1 shows FD student answer sheet to recognize different figures from a picture. There are some example figures in the question, then student has to answer a certain different figure. This question is related to spatial performance which one of its part is seeing figure from different angle, but not mentally moving the object [22]. Student can answer this question perfectly. Student may have a good experience with pictures and has a good spatial performance. This is also supported by interview result that student can differentiate figures although it looks from different angle. Student knows that rectangle has right angle sign in the given picture. On part i), student does not see right angle sign in picture at the question, so she stated that the figure is a parallelogram.

Figure 2 shows the same kind of question. It shows the difference answer between FD student and FI student on part i). FI student can not answer correctly at this part. Student may have lower spatial performance. It is connected with math anxiety. So student need to explore more with pictures. It is supported with Hoffer who said that students who are anxious about learning mathematics may not perform well on spatial tasks, students need to explore more with pictures and manipulative devices [14]. When interview, student also could not see the difference between rectangle and parallelogram picture. He could not see figure well from different angle. But student could answer correctly question in part (ii) and (iii) as FD student.

Figure 3 shows FD student answer sheet to notice properties of rectangle, parallelogram, square and rhombus. Students need to understand visual representation of those figures which is part of spatial performance [22]. Students were asked to answer the question based on angle, length of side, and pair of parallel side. Student can answer this question perfectly. It means students have a good spatial performance. Students can think well to review those figures, to notice the properties of each

Figure 4. FD student answer sheet in question b at level 1 van Hiele.
figures [14]. Interview result also shows that student notices the properties of figure goodly. Student can review the figure based on angle, length of side, and pair of parallel side correctly.

![Figure 5. FI student answer sheet in question b at level 1 van Hiele](image)

Figure 4 also shows FI student answer sheet to notice properties of rectangle, parallelogram, square and rhombus. But the result shows that FD students have better result than FI students. This contradicts with Rayner and Riding [16] who said that FI students are better than FD students in analysis and also Witkin statement that FI students is better in mathematics and science than FD students [21]. Based on interview result, student actually knows the properties, but they did not answer completely. Some of them also just know some properties of figure. So it makes their result is not better than FD students.

At question c, students were asked to recognize interrelationships between different types of rectangle, parallelogram, rhombus, and square. Kind of this question is related with the statement of Hoffer that in learning geometry, teachers also need to ask students question which encourage them to review the word of a figure, to see how the figure relate to other figures [14]. Result shows that all FD and FI students still can not answer this question correctly, anyone can recognize interrelationships between different types of figures. From the interview, actually students have learned about it. This may be most students are still anxious to learn mathematics so that they also do not perform well on spatial tasks [14].

4. Conclusion

Based on the results of research and data analysis results, it can be concluded that most of students have FD cognitive style. Most of FI students’ score show a better result than FD students’ score in each level of van Hiele. There is not specific pattern to describe students' visual skills for each van Hiele level. It does not indicate that the higher the level of van Hiele achieved by students, the better the visual skills of students. Because of time and participant number limitation, this study needs suggestion and improvement in the next study.

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