Elementary school students visual spatial comprehension based on van Hiele Theory: the case in Madiun, East Java, Indonesia

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Abstract. This study presents partial result from the project “Geometry in Flipbook Multimedia: A Technology Role in Improving Mathematical Learning Quality in Madiun”, which was undertaken to explore the skill of geometry and passing rate of van Hiele’s geometric thinking level, especially for the first three level. The material focus of the study is a two-dimensional figure and reviewed from basic skill aspect of geometry (visual, verbal, drawing, logic, and application). The participants were 30 students in the 6 grade of elementary school in Madiun, East Java. The data collecting technique for this study there are a test instrument of van Hiele geometry (VHG) and an interview’s instrument about characteristics geometry basic skill. After the test, twelve students from participants were randomly selected interviewed to determine their geometry basic skill. This study found that (1) most of the students of 6 grade can only reach the first level is about 69%, the passing rate at the second level test is about 49%, and at the third level, the average of students’ achievement is 35%, (2) if viewed from five basic skills of geometry, most of the students have a low mastery, and (3) the achievement of grade six students are inclined high in first level and low in third level based on van Hiele’s Geometric Thinking Level.

1. Introduction

Geometry as one of the mathematics branch occupies a particular position in mathematics curriculum with more material portion. Geometry is one of the most important topics in mathematics (Ministry of Education of Taiwan, MET, 1993, 2008 [1], including in Indonesia, from elementary to secondary school [2]. The tendency of learning geometry can improve the ability in solving the Mathematics problem. “ ... many people enjoy the challenge of solving riddles and other types of puzzles. The studied geometry offers similar intriguing challenges ...” [3]. Therefore, geometry is a basic skill to be mastered. It is important in architecture and design, in engineering and in various aspects of construction work [4]. However, In a traditional geometry course, students are told definitions and theorems and assigned problems and proofs; they do not experience the discovery of geometric relationships, nor invent any mathematics [5]. A study by the author revealed that most teachers have difficulties in delivering some geometry concepts [5]. In the other research, one of the problems in teaching and learning geometry is that students have lack basic foundation in mathematics, students can not solve the problem even when the examples are given [6]. Therefore, a deep conceptual understanding and the ability to visualize geometrical properties at the elementary level are most needed for the students to progress to the higher level learning of geometry [7-8].
The aim of the geometry is learning the properties of the geometrical shapes in plane and space, finding the relations between them, describing the geometrical position, explaining transformation and proving geometrical arguments [9]. Learning theory which is particularly developed in geometry learning then the positive implication has already been admitted toward geometry thinking process is van Hiele theory. This theory is developed by two Dutch educators, Pierre Marie van Hiele and Dina van Hiele-Geldof. Based on van Hiele theory, someone will pass five thinking development level in learning geometry. They are the 1st level (Visualization), 2nd level (Analysis), 3rd level (Informal Deduction), 4th (Deduction) and 5th (Rigor).

Some journals which review about van Hiele implementation, among others; are as follows. A Study of van Hiele of Geometric Thinking among 1st through 6th Graders, state that “... for elementary school students, the passing rates of boys and girls have no significant differences in van Hiele’s geometric thinking level.” [10]. The study towards Students’ Geometry Skill Analysis in Solving Geometry Problem Based on van Hiele’s thinking level, by giving conclusion that the students in 1st level of visual skill only can determine the kind of quadrangle plane based on the shape; the students in 2nd level can convey the characteristics of plane's picture, and the students in 3rd level can explain the relationship among all kinds of quadrangle with the common characteristics [11], also a study towards how far the effect of geometry thinking level based on van Hiele Theory to the elementary school's teacher [12].

The van Hiele of thinking level theory explains that geometry thinking level which consists of five levels has to be a sequence and hierarchical [9]. At the first level (Visualization), students learned geometry through visualization. A child recognizes rectangle by its form and a rectangle seems different to him than a square. At this first level, students identify and operate on shapes (e.g., squares, triangles, etc.) and other geometric parts (e.g., lines, angles, grids, etc) based on appearance [10].

At the second level (Analysis), a student may realize that the opposite sides, and possibly even the diagonals of the rectangle, are congruent, but will not notice how rectangles relate to squares or right triangles. Students’ analyze the properties of figures: “rectangles have equal diagonals” and “a rhombus has all sides equal,” but they do not explicitly interrelate figures empirically, and use the properties to solve problems [10].

At the third level (Informal Deduction), a student will understand why every square is a rectangle, but may not be able to explain, for example, why the diagonals of a rectangle are congruent. At this level, properties are ordered, and are deduced one from another: one property precedes or follows another property [10]. The focus of this study was elementary school students and the first three van Hiele levels.

Linked to those stated above, the fact shows that the results of learning geometry in 6 grade in Madiun is still low. The student’s ability is just still about recognizing the shape of geometry based on the visual characteristic and appearance. It is not in line with the geometry thinking level that should be achieved by the 6 grade, which is supposed to be on the first three van Hiele levels (Informal Deduction), although naturally, a student will have different geometry thinking level with other students. Moreover, if it is reviewed from the basic skill aspect of geometry, almost all of the students haven’t been able yet to apply the learning skills comprehensively which consist of visual, verbal, drawing, logic, and application skill. Most of the students haven’t been able yet to determine whether rectangle, square, and rhombus are a parallelogram or not. Therefore, this study’s purpose is for knowing the accomplishment of elementary school grade six students’ geometry thinking level in Madiun, especially on the first three level of van Hiele levels which is reviewed from basic skill aspect of geometry (visual, verbal, drawing, logic, and application). The achievement of students’ thinking level can be known from the result of research. However, by knowing how far geometry thinking level in elementary school student also will influence the geometry learning quality especially in Madiun.

It is also known, that almost most of the study about geometry learning is held in the secondary school. Most researchers focus on the geometrical curricula of secondary school. Thus, the research is expected to provide useful information for elementary school teachers in Madiun. Therefore, students' knowledge quality is not determined by their knowledge accumulation, but it is determined by the
thinking process used. Thus, the teacher must provide a learning experience which is suitable with the students’ geometry thinking level in order to make them have thinking maturity when they face the process. Learning experience which is given by the teacher can be formed as good learning method or learning media.

2. Methods

This study is a qualitative study with a case study by taking 30 students in 6 grade of Sekolah Dasar Negeri 05 Madiun Lor. The data collecting technique for this study are a test and an interview about geometry skill characteristics. The test consists of 25 multiple choice questions with the scoring based on the test of van Hiele geometry (VHG) as developed by Usiskin [12], in the project “Van Hiele Levels and Achievement in Secondary School Geometry” (CDASSG Project). In the VHG Test, each level has five questions. At the first level (Visualization) is the level to identify geometry identification phase. The test material of this level is recognizing the shapes of the plane such as triangle and square. They use simple language. They do not identify the properties of geometric figure [13].

At the second level test (Analysis) is the test to identify various characteristics of triangle and square, while test material of VHG Test for the third level (Informal Deduction) is identifying the connection among geometry planes. The fourth level (Deduction) is the test for measuring the students' ability in taking the conclusion using definition and characteristic, also taking the purpose of verification. Last, on VHG Test is the fifth level, it is Rigor. On this test, the material is the students' accuracy in determining the basic principles of verification. “..... that higher levels of questions Van Hiele are able to ask, understand and answer only students with higher levels of intelligence [7]. However, a researcher only focuses on the first three level of van Hiele Theory, therefore the discussion will be focused on van Hiele’s geometric thought of Visualization, Analysis, and Informal Deduction.

If the student answers three, four, or five first-level questions correctly, he/she has reached the first level. If the students (a) answered three questions or more correctly from the second level; (b) met the criteria for the first level; and (c) did not correctly answer three or more questions, from levels 3, 4, and 5, they were classified in the second level [10]. Therefore, using the same criteria set by Usiskin [12], the passing rate of this study was set at 60%.

In the interview result, there are categories of toward reduction result data based on geometry skill which consists of visual, verbal, drawing, logic, and application skill. Those data are adjusted with the geometry skill indicators based on van Hiele thinking level theory in that test's result. The data validity technique used in this study is a triangulation method, they are the test and interview method. This triangulation emphasizes to the method use or collection technique which is different from the same data [14].

3. Result and discussion

Analysis result of VHG Test towards 30 students are: students’ accomplishment in first level (Visualization) is 69%, in second level (Analysis) is 49%, in third level (informal deduction), the passing rate is 35%. Those data are shown in Figure 1.

Based on the graphic on Figure 1, van Hiele’s thinking level accomplishment of grade six students are inclined high in the first level and low in the third level. Moreover, from the test results known how many students who answered right and wrong answer for each question on the VHG Test shown in Table 1.

Based on Figure 1 which is supported by the Table 1, shows that the students only can reach the first level, that is Visualization. This phase shows that the majority of students can answer correctly, even in question number 1 and 2, all the students answer correctly. In question number 3, for about 86% students answer correctly. The interesting thing is that when the students identify that rectangle is a square (43%), but there are no students who answer correctly when determining that rhombus is a parallelogram (3%). The students in this phase can recognize the geometry shape visually.
At the second level test, the average is about 49% students who answer correctly. Based on the criteria, it shows that the students can not reach the analysis level. At this level, for about 97% students answer correctly in question number 7, it is determining the characteristics of the rectangle. The students' comprehension towards the characteristics of a rhombus is also good (73%). Although the students cannot answer correctly (0%) in question number 10, it is about the intersection of two circles which forms square if connecting the line from the center of the circle. It can be said that the students haven't already recognized geometry characteristics yet.

At the third level, the average of students' achievement is 35%. Actually, it is expected that the students in the basic degree can reach this level, but in fact, the majority of the students cannot answer correctly toward 5 questions given. The higher students' achievement (80%) is when they answer correctly in question number 13, it is determining rectangle from three planes given. The minority of the students (7%) only can answer correctly when determining the characteristics of square and rectangle from some questions given, for about 3% students who answer correctly in question about the characteristics which the rectangle has, but the parallelogram doesn't.

When the students are faced with geometry object visually, they can recognize some planes' shape. However, almost all of the students only can answer correctly the most in two questions in 2nd level (Analysis), because the students' ability in identifying mathematical characteristics is still low.
Interview result towards 30 students are students' geometry basic skill characteristics which are categorized in five levels, they are visual skill, verbal skill, drawing skill, logic skill, and application skill is as follows.

In visual skill which is had by the students consists of the ability only in being able to determine the kind of plane based on the shape appearance, in explaining the plane’s characteristics based on the picture can't be specific, only focused on the number of side, angle, and hasn't been able to explain the relationship among many kinds of plane yet. Most of the students haven’t been able yet to determine whether rectangle, square, and rhombus are a parallelogram or not.

The verbal skill of the students consists of the ability in categorizing the correct name for some planes, it hasn't been able to define a plane based on mathematical characteristics, because the characteristics which are known only at angle size, the side length or determine the number of sides. Also in this ability, the students haven't been able yet to show through the sentence about how is the relationship among the planes.

In drawing skill mastery, the most students only be able to draw a plane based on their visual level, haven't been able to construct the plane's picture based on the characteristics given. The students only remember the planes' shape based on the visualization given. It's same as logic skill, in this basic skill the students can understand many planes' shape in many positions and mention those planes’ name because they realize the shape's similarity from some planes shown.

The students' application basic skill consists of the ability for connecting information like object or picture of a plane which is observed and developing in geometry model (without using the scale), can explain geometry characteristics of a plane but hasn’t been able to use geometry model in a problem-solving.

4. Conclusion
According to the analysis and findings, this study found that most of the students of 6 grade can only reach the level of thinking geometry based on van Hiele’s theory at the first level (69%), the passing rate at the second level test is about 49%, and at the third level, the average of students' achievement is 35%, therefore based on the criteria VHG Test known that the students can not reach the Informal Deduction level, the results of interview obtained that students can only determine the type of planes' shape based on the appearance of the shapes: at the verbal skill, most of the students can group the correct names for the given planes’ shape; at the drawing skill, students can show his/her abilities to draw a two-dimensional figure according to the special characteristics of planes’ shape; at the logical skill, most of the students can mention the figure name correctly if viewed by various positions; while at the application skill, the students can explain the characteristics of figure but they haven’t been using the geometry’s model to solving the problems, and the achievement of grade six students are inclined high in the first level and low in the third level based on van Hiele’s Geometric Thinking Level.

References
[1] Ministry of Education of Taiwan (MET) (2008). Grade 1-9 Curriculum Guidelines—Mathematics. Taipei, Taiwan: Author. (In Chinese)
[2] Jupri A 2017 J. Phys.: Conf. Ser. 895 012080
[3] Lunce L M 2006 J. Appl. Educ. Technol. 3(1) 37-45
[4] Abdullah A H and Zakaria E 2013 102 251-266
[5] Sariyasa 2017 J. Phys.: Conf. Ser. 824 012057
[6] Adolphus T 2011 Int. J. Emerg. Sci. 1(2) 143-152
[7] Hardianti D, Priatna N and Priatna B A 2017 J. Phys.: Conf Ser 895 012088
[8] Abu M S, Ali M B and Hock T T 2012 Procedia Social and Behavioral Sciences 64 75
[9] Yildiz C, Aydin M and Köce D 2009 Proced. Soc. Behav. Sci. 1 731
[10] Hsiu-Lan Ma 2015 Eurasia J. Math. Sci. Technol. Educ. 11 1181
[11] Nur’a'ini M 2014 Electron. J. Learn. Math 2 54
[12] Usiskin Z 1982 Van Hiele Levels and Achievement in Secondary School Geometry. CDASSG Project.
[13] Haviger J and Vojkuvková I 2015 Proced. Soc. Behav. Sci. 171 912
[14] Budiyono 2017 Introduction To The Methodology Of Educational Research (Surakarta: UNS Press)
[15] Havigerova, Marie J and Iva B 2013 Int. J. Early Child. Learn. 20 63