

Geometric Reasoning Ability Based on *Van Hiele Theory* by *Geogebra Software*

A M Ramlan^{1*}, E Cahyono², Fahinu³, and F Hali¹

¹ Faculty of Mathematics Education, Sembilanbelas November Kolaka University, South East Sulawesi, Indonesia, Kolaka 93517

² Faculty of Mathematics and Natural Science, Halu Oleo University, South East Sulawesi, Indonesia, Kendari 93132

³ Faculty of Mathematics Education, Halu Oleo University, South East Sulawesi, Indonesia, Kendari 93132

*E-mail: marianiramlan@gmail.com

Abstract. The difficulty of students in solving geometric reasoning problems which are based on Van Hiele's levels is still low so that the right alternative solution is needed. For that reason, this research aims to answer those three main objectives. First, this study determines the difficulty experienced by the students. At second, this research identified the factors which cause the difficulty experienced by students in solving geometric reasoning problems based on van Hiele theory by GeoGebra software. At third, this research tried to determine the steps which are required to be taken to overcome the students' difficulties in solving geometric reasoning problems based on van Hiele theory by GeoGebra software. The type of study is a descriptive study with a qualitative approach. The results showed that students' geometrical reasoning ability was still in the low category; the causal factors are the students were rarely trained in geometric reasoning and lack of self-confidence. The step that should be done is by using van Hiele theory to detect the difficulty experienced by the students, including technology media such as GeoGebra software.

1. Introduction

Geometry is one of mathematics brach which has a greater opportunity to be mastered by students than other branches. The reason is that geometric ideas are already known by the students as earlier before they enter school, for example students' earlier knowledge ababout lines, planes, and spaces [1]. Geometry not only develops the students' cognitive ability but also helps the students in the formation of memory namely from concrete objects to abstract or to geometrical reasoning processes so that geometry is an important material in mathematics learning [2]. Actually, the field reality showed that most Senior High School students are still lack of mastery in geometry material. Therefore, teachers must provide learning experiences that are appropriate to the level of students' geometrical thinking to lead students thinking mature facing the process. Also, the teacher can form a learning experience by provided such method or by use instructional media [3]. In this case, geometric requires media to facilitate learning as well as a tool, namely GeoGebra. It is used to measure geometric reasoning abilities based on van Hiele's theory. Because if the geometry and learning materials not adjusted, it will cause a lack of success in learning mathematics. Knowing Van Hiele's level of problems using GeoGebra in making question instruments will be more helpful to get Van Hiele level information on

students who have problems or the level of geometric thinking. Then, the right handling alternative solution are able to apply to achieve the optimal learning outcomes. It also because

In line with the above idea, this research tried to (1) find out the difficulty experienced by students in solving geometric reasoning problems based on van Hiele theory by GeoGebra software; (2) identify the causes of difficulty experienced by the students in solving geometric reasoning problems based on van Hiele theory by GeoGebra software; and (3) determine the steps which are required to be conducted to overcome the students' difficulty in solving geometric reasoning problems based on the van Hiele theory by GeoGebra software.

Based on the previous observation, it stated that the three-dimensional figure is the most difficult of the mathematics learning material for the tenth grade at Senior High School or Islamic Senior High School. It is because the three-dimensional figure is an abstract concept. In addition, there are several problems occur namely (a) the students' skills in drawing and using the tools to draw three dimensional figure is still low; (b) the students' ability to understand the mathematical concepts is still unsatisfactory; (c) some students only rely on memorization without understanding the concept so that they make mistakes on finishing the problem; and (d) the prerequisite material includes straight lines, angles, the area of two dimensional figure, trigonometry and the requisites for Pythagoras theorem application have not been mastered by some students [4].

To resolve students' difficulties in learning geometry, it is recommended to apply the theory of van Hiele. According to van Hiele's theory, the students work by the stages of students' thinking, so students are increasingly interested in learning [5].

The skills to use learning media, namely GeoGebra, to complement van Hiele's theory are expected to be useful to provide the information regarding the difficulties experienced by the students. GeoGebra is a dynamic mathematics software used as a tool in mathematics learning specifically to make instruments to measure students' geometrical comprehension based on van Hiele's theory. However, this software is developed for the mathematics teaching and learning process in observed schools at least three uses namely the mathematics learning media, the mathematics teaching materials, and the mathematics problem solving [6].

Later on, Van Hiele theory is one of the theories that can measure students' geometrical abilities. As the name of the theory, this theory was presented by Dina and Pierre van Hiele in 1986. They researched students' geometrical thinking at school. According to this theory, there are five levels experienced by the students in learning geometry. The use of levels here is not to categorize the students but to know about the students' geometrical thinking ability gradually through these five levels. Based on the research of Van Hiele theory, students are usually at level 0, Junior High School students are usually at level 0 and 1, while Senior High School students are at level 2 [2]. This study is limited to level 3 (formal deduction).

Pierre van Hiele and his wife Dina van Hiele-Geldof were Dutch researchers and teachers. They had personal experience with difficulties which their students had in learning geometry. Therefore, they dealt with these problems in detail. The theory originated in their theses at the University of Utrecht in 1957 [7]. These research findings provide mathematics teachers insight into how students think and what difficulties they face while learning geometry [8].

The indicators of van Hiele thinking the level theory that had been adapted to the Three Dimensional material of modified [1] as in Table 1 below:

Table 1. Indicator of van Hiele Thinking Level in the Subject of Three Dimensional Space

Thinking level based on van Hiele theory	Characteristics	Thinking Level Indicators
Level 0 (visualization)	Students' thinking objects are still dominated by shape and what a shape looks like visually.	<ul style="list-style-type: none"> ▪ Students can visualize: <ul style="list-style-type: none"> - The position of points, lines, and planes in space - the surface area of geometric shapes - distance in geometric shapes - The angle in geometric shapes - Plane section with geometry
Level 1 (analysis)	Students start to recognize and apply a geometric idea, to correctly describe various properties, and also to able to identify the figure as a part of a bigger figure.	<ul style="list-style-type: none"> ▪ Students can analyze: <ul style="list-style-type: none"> - The position of points, lines, and planes in geometric shapes - the surface area of geometric shapes - distance in geometric shapes - The angle in geometric shapes - Plane section with geometry
Level 2 (Informal Deduction)	Students can sort and relate several geometric ideas logically, understand definitions, and conclude by giving arguments informally	<ul style="list-style-type: none"> ▪ Students can conclude by giving arguments informally based on the given information.
Level 3 (Formal Deduction)	Students understand the meaning of deduction so that they can prove based on axiom, theorem, or formula.	<ul style="list-style-type: none"> ▪ Students can prove by giving explanations formally based on axiom, theorem, or formula.

The advancement from one level to the next level depends more on the education or learning experience than age or maturity. Some experience can ease or obstruct the advancement in a level or to a higher level [9].

The completion of three-dimensional space problems requires not only student skills but also thinking and reasoning. Here are the difficulties of students when learning material that leads students to make mistakes in solving questions about three-dimensional space. The number of mistakes made by students in solving the questions can be a clue on how far students have mastered the material. From the mistakes made by students, the causes of student errors can be further investigated and then must immediately get a complete solution. This solution is taken by analyzing the root of the problem that is the cause of mistakes made by students then an alternative solution is sought so that the same error will not be repeated in the future [4].

2. Methods

This research is a descriptive study using a qualitative approach. This research was done in class XI of SMA Negeri 1 Wundulako located in Jl. Guro no. 05 Lamekongga, Wundulako Subdistrict, Kolaka Regency, Southeast Sulawesi Province. The research subject is a three-dimensional figure.

The data collection techniques used were (1) the test method and (2) the semi-structured interview method carried out on the subjects who were selected. The test given in this study is a diagnostic test. "Diagnostic tests are tests that are used to figure student weaknesses so that based on these weaknesses

can be given the right treatment [10]. The instrument used are the four items of students' geometrical reasoning ability, which consists of four ability levels namely visualization, analysis, abstraction, and formal deduction.

The category distribution for the students' score of geometrical reasoning ability used the criteria guideline stated [11] in the following Table 2:

Table 2. The Categorization of Geometrical Reasoning Ability

Score	Category
$80 \leq x \leq 100$	High
$60 \leq x < 80$	Intermediate
$0 \leq x < 60$	Low

In qualitative research, the data validity can be check by triangulation and extension of participation. Triangulation is a technique of checking the validity of data that uses something else outside of the data for checking or as a comparison to that data [10]. Triangulation in this study is a triangulation method, which is by comparing the test results data verified by interview, and observation [4].

3. Results and Discussions

The test result of geometrical reasoning skill consisted of 4 indicators, namely visualization, analysis, abstraction or informal deduction, and formal deduction. The test result was presented descriptively in the form of a table. Generally, the result of the students' geometrical reasoning skill was presented in the following table 3:

Table 3. The Test Result Data of Geometrical Reasoning Skill

Geometrical Reasoning Skill	
Number of Respondents	30
Average	42.50
Median	47.50
Modus	60.00
Standard Deviation	24.591
Variant	604.741
Minimum Score	5.00
Maximum Score	90.00
Total Score	1275.00

The percentage of students and the average score of students' geometrical reasoning ability for each category of the high group, intermediate group, and the low group were presented in the bar diagram in the following figure 1:

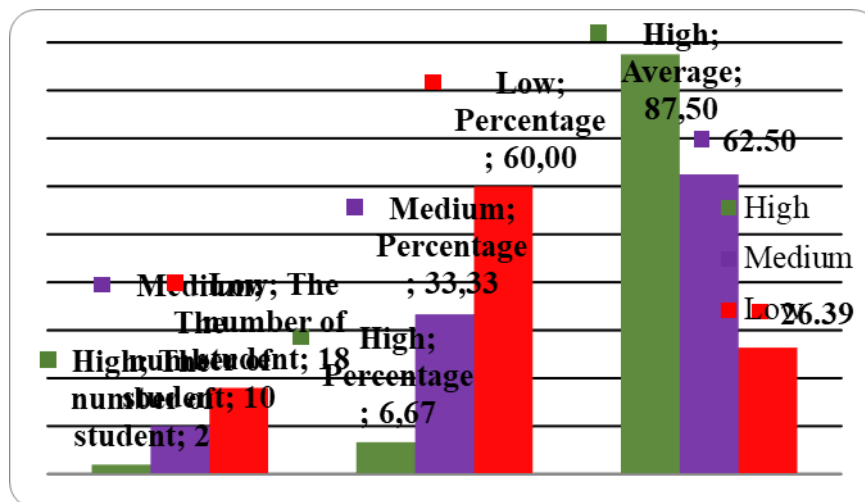


Figure 1. The Percentage of the Number of Students and the Average Score of Geometrical Reasoning Skill

The data obtained from the results of the geometric calculation tests of students for each level were presented in the following table 4:

Table 4. The Results of Geometric Reasoning Analysis

Level of Thinking	N	Percentage (%)	Average
Visualization	10	33.33	3.07
Analysis	2	6.67	2.03
Abstraction	2	6.67	1.90
Formal Deduction	0	0.00	1.50

Based on table 4, the four levels of geometric reasoning, were not maximally achieved.

The difficulties experienced by students at the level of analysis were that students were not able to analyze geometric object based on its characteristics. It was only ten students whose solutions were almost fully complete and correct with a score of 5 each. No student was able to achieve maximum scores in the level of abstraction and formal deduction. Based interview, the students got difficulty to answer the questions based on van Hiele's theory due to several things. The students rarely practiced geometrical reasoning questions, students were lack of confidence, and there was no teacher's comprehension of problematic level information and required appropriate alternatives and lack of use of learning media. From the information, it also was required to familiarize van Hiele's theory to students by practicing geometric reasoning skills and identifying problematic levels, besides the use of appropriate media like GeoGebra is a mathematics dynamic software used as a tool in mathematics learning specifically to make instruments to measure students' geometrical comprehension based on van Hiele's theory [6].

The benefit of this research is to inform educators that the Van Hiele's theory combined with the use of GeoGebra software can be an alternative in anticipating students' difficulties in learning geometry. In addition, this research can be a benefit for coastal communities who want to develop their potential resources such as making more contextual instruments with coastal areas and utilizing GeoGebra software based on Van Hiele's theory, either in geometry learning or mathematics learning.

4. Conclusion

This research concludes three main points. At first, the student's geometric reasoning skill is categorized into a low level. Second, the difficulty factors students faced are the students' lack of confidence, the teacher's comprehension, and the lack of learning media, especially GeoGebra

software. At third, the recommendation step is by using Van Hiele theory to detect the difficulty experienced by the students, including technology media such as GeoGebra software. At last, it is also necessary to pay attention to the not maximally achieved students' level of thinking or geometric reasoning abilities.

References

- [1] Khoiriyah N, Sutopo dan Aryuna D R 2013 Analisis Tingkat Berpikir siswa Berdasarkan Teori van Hiele pada Materi Dimensi Tiga ditinjau dari gaya Kognitif Field Dependent dan Field Dependent *Jurnal Pendidikan Matematika Solusi* vol. 1 (1) p 18-30
- [2] Khotimah H 2013 *Meningkatkan Hasil Belajar Geometri dengan Teori van Hiele*. Prosiding Seminar Nasional Matematika dan Pendidikan Matematika, Universitas Yogyakarta, 9 November 2013 p. 9
- [3] Andini S, Fitriana L and Budiyono 2018 Elementary School Students Visual Spatial Comprehension Based on van Hiele Theory: the case in Madiun, East Java, Indonesia *J. Phys.: Conf. Ser.* **983** 012097
- [4] Hidayat B R, Sugiarto dan Pramesti 2013 Analisis Kesalahan Siswa dalam Menyelesaikan Soal pada Materi Ruang Dimensi Tiga ditinjau dari Gaya Kognitif Siswa *Jurnal Pendidikan Matematika Solusi* vol 1(1) p 39-46
- [5] Junedi B 2017 Penerapan Teori Belajar Van Hiele pada Materi Geometri di Kelas VIII MSE (*Journal of Mathematics Education and Science*) vol 3(1) p 1-7
- [6] Nur I M 2016 Pemanfaatan Program GeoGebra dalam Pembelajaran Matematika *Delta-Pi: Jurnal Matematika dan Pendidikan Matematika* vol. 5(1) p 10-19
- [7] Vojkuvkova I 2012 The van Hiele Model of Geometric Thinking *WDS'12 Proc. Contrib. Pap. 1* p 72
- [8] Halat E 2008 In-Service Middle and High School Mathematics Teachers: Geometric Reasoning Stages and Gender, *The Mathematics Educator* vol 18(1) p 8–14.
- [9] Nuraeni E 2008 Teori van Hiele dan Komunikasi Matematik (Apa, Mengapa dan Bagaimana) *Seminar Matematika dan Pendidikan Matematika* p 124
- [10] Arikunto S 2009 *Dasar-dasar Evaluasi Pendidikan. Edisi Revisi* (Jakarta: Bumi Aksara)
- [11] Kadir 2010 *Penerapan Pembelajaran Kontekstual Berbasis Potensi Pesisir Sebagai Upaya Peningkatan Kemampuan Pemecahan Masalah Matematik, Komunikasi Matematik, dan Keterampilan Sosial Siswa SMP* (Disertasi: unpublished) p 251