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Analysis of the Geometric Thinking Stage of Madrasah Tsanawiyah Students Based on Van Hiele's Theory

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ABSTRACT

In the process of learning mathematics, especially geometry, teachers must pay attention to the level of ability possessed by students. Van Hiele suggests that there are five stages of thinking that students will go through in learning geometry: the visualization stage, the analysis stage, the informal deduction stage, the deduction stage, and the rigor stage. Each stage of thinking will be passed by students sequentially without passing any of the previous stages. This study aimed to identify and describe the geometric thinking stages of high school students. The first is based on van Hiele's theory. The research method used in this research is descriptive quantitative. This research was conducted at MTs (Madrasah Tsanawiyah) An-Nur, Cirebon City, with a population of 318 students and a sample of 72 students selected using a purposive sampling technique. The data collection technique used is in the form of a Van Hiele geometric thinking stage test with 25 multiple choice questions divided into five subtests. The results showed that 29.17% of students were in stage 1 (visualization), 25% of students were in stage 2 (analysis), and 6.94% of students were in stage 3 (informal deduction). There are still students who have not entered the van Hiele geometric thinking stage (at stage 0), namely 13.89%. As for the students who could not determine their van Hiele geometric thinking stage, as many as 25%. The highest stage achieved by students was stage 3 (informal deduction), so no student reached stage 4 (deduction) and stage 5 (rigor). In general, the geometric thinking stage of MTs (Madrasah Tsanawiyah) An-Nur students is at stage 1 of van Hiele's geometric thinking.

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1. INTRODUCTION

Mathematics is one of the subjects taught at every level of education in Indonesia, from Elementary to Senior High School. Mathematics subjects must be given to all students starting from elementary school to equip students with the ability to think

logically, analytically, systematically, critically, and creatively, as well as work together [1].

According to Johnson and Rising [2], mathematics is a pattern of thinking, organizing patterns, and logical proofs; mathematics is a language that uses carefully defined, clear, and accurate terms, its representation with symbols and solid, more in the form of language. Symbols for ideas rather than sounds. This means that learning mathematics will undoubtedly be able to direct students to think logically, systematically, critically, and practically so that in its application, they can be more sensitive to the problems around them.

One of the branches of mathematics taught in schools is geometry. Geometry is one part of school mathematics taught starting at the elementary level. In geometry, objects are studied in the form of facts, concepts, and principles of geometry. By mastering these objects well, it is hoped that students' verbal, visual, drawing, and logical thinking skills can grow and develop [3].

Geometry occupies a particular position in the school mathematics curriculum because of its many concepts and applications in everyday life. Geometry has a greater chance of being understood by students than other branches of mathematics, but the evidence in the field shows that the learning outcomes of geometry are still low. Based on the research of Pradika & Murwaningtyas [4], in learning geometry, junior high school students memorize formulas but do not know how to use them in solving problems. The average student does not understand the terms and symbols used in geometry problems, especially in the questions presented as story questions. This shows that students have learned concepts at a high level but have not understood the basics of geometry itself.

Based on the preliminary study, it was found that in learning geometry, students had difficulty understanding the questions presented in the form of story questions; students better-understood geometry questions presented in the form of pictures. In addition, students also do not understand the use of geometric formulas in solving problems given by the teacher.

In delivering mathematics learning material, especially geometry, the teacher must pay attention to student ability levels. The teacher must know the level of students' mental development and how teaching should be carried out to suit those levels of development. In other words, Learning that does not pay attention to the level of students' mental development will most likely result in students experiencing difficulties because what is presented to students is not following the students' ability to understand and absorb the material provided [5]–[9].

One opinion expert who also pays attention to the level of cognitive ability is van Hiele. The research conducted by van Hiele gave birth to several conclusions regarding the stages of children's cognitive development in understanding geometry. In van Hiele's theory [10]–[12], there are five stages of understanding geometry, namely: introduction (visualization), analysis, sequencing (informal deduction), deduction, and accuracy (accuracy). Each stage describes the process of thought applied in the context of geometry. The stages describe how we think and what kinds of geometric ideas we think about, not how much knowledge we have.

The introduction stage is the first stage in the geometric thinking stage developed by van Hiele. Students are new to geometric shapes such as balls, cubes, triangles, squares, and other geometric shapes at this stage. If, at the introduction stage, the child does not yet know the properties of geometric shapes, not so at the analysis stage. At this stage, students can understand the properties of geometric shapes and mention the regularities contained in these geometric shapes [13]–[17]. The ordering stage is the third stage of van Hiele's geometric thinking stage. At this stage, students understanding of geometry is even more improved than before, which only recognizes geometric shapes and their properties, so at this stage, students can know the related relationships between a shape geometry with other geometric shapes.

The deduction stage is the next stage of van Hiele's geometric thinking stage. At this stage, students can understand deduction, which is to conclude deductively. The deductive inference is concluding specific things. The last stage of a child's cognitive development in understanding geometry is the stage of accuracy. At this stage, the child already understands how important the accuracy of the basic principles that underlie proof is. Children at this stage already understand why something is used as a postulate or postulate.

Junior high school students or equivalent are expected to be able to progress to the level of informal deduction in geometric thinking. Thus, junior high school students can learn geometry through three stages, namely the introduction stage (visualization), the analysis stage, and the sequencing stage (informal deduction) [18]. However, the results of Syaifullah's research [19] show that most students (41.9%) have just reached stage 2 (analysis) of van Hiele's geometric thinking, so the geometric thinking stage of students is still not as expected.

2. METHOD

Under the research objective, namely, to analyze the geometric thinking stage of MTs (Madrasah Tsanawiyah) An-Nur Cirebon students based on van Hiele's theory, this study used descriptive quantitative methods. This study will conduct a Van Hiele geometric thinking stage test on junior high school students. The research data from test scores will be analyzed to determine the students' geometric thinking stages.

This study's population was all MTs (Madrasah Tsanawiyah) AN-Nur Cirebon City students, consisting of 9 classes totaling 318. The samples in this study were students of class VIII A and VIII B MTs (Madrasah Tsanawiyah) AN-Nur Cirebon City, amounting to 72 people. In determining the sample, the researcher used a purposive sampling technique, namely, determining the sample with specific considerations.

In this study, the students' geometric thinking stage test was conducted using multiple choice questions for all sampled respondents. The research results were written by grouping and describing the students' geometric thinking stages based on van Hiele's theory. The approach in this study follows the steps of descriptive quantitative research work, namely the data in the form of test scores which are then analyzed to determine the students' geometric thinking stage.

The instrument in this study used a multiple choice test instrument. A test instrument is a tool used for measurement and assessment, usually in the form of some questions/questions given to be answered by the subject under study (students/teachers).

The test instrument was used to determine the students' geometric thinking stage in van Hiele's theory. Each question is built to measure the students' geometric thinking stage based on van Hiele's theory. The instrument is in the form of multiple choice questions with 25 items divided into five subtests. Each subtest represents one stage of van Hiele's geometric thinking and consists of 5 questions. The test result data is then converted into a numeric language. Each correct number is given a score of 1; if incorrect, it is given a score of 0. Students are considered to have reached a stage if they meet the criteria for doing correctly at least three out of 5 questions in each subtest. Students are considered to have reached stage 2 (analysis), stage 3 (deduction), stage 4 (informal deduction), and stage 5 (rigor) if the student has reached the previous stage.

3. RESULTS AND DISCUSSION

3.1. Results

The analysis phase begins with reading the data obtained from the data collection results. The data was obtained in the form of test scores obtained by students from the results of the van Hiele geometry thinking stage test. In determining the geometric thinking stage, students are not only based on the scores obtained by students in each subtest with the criteria of at least 3 of the five questions being answered but also must be determined under one of the characteristics of van Hiele's geometric thinking, namely that each stage must be passed individually. Massage without skipping the previous stage. The results of the data analysis of the students' geometric thinking stage obtained are as follows:

1. Students' Geometry Thinking Stage 0
   Not all students can meet the criteria for van Hiele's geometric thinking stage. Students who do not meet the criteria for answering at least 3 of the five questions on each subtest can be categorized in stage 0. Based on the results obtained, students who do not meet the criteria at all in each subtest of van Hiele's geometric thinking stage are 13.89 %. This shows that only a small number of students have not entered the van Hiele geometric thinking stage.
2. Thinking Geometry Students Stage 1
   Students included in the category of being in stage 1 meet the correct criteria for 3 of 5 questions in subtest one but do not meet these criteria in other subtests. The analysis found that the percentage of students in stage 1 of van Hiele's geometric thinking was 29.17%. This shows that less than half the number of students are included in the category of stage 1. At stage 1, students are familiar with the forms of the geometric plane as a whole but do not yet know the properties of the geometric plane.
3. Thinking Geometry Students Stage 2
   Stage 2 is the analysis stage, where students already understand the properties possessed by the geometry field but do not understand the relationship between the geometric fields. Students categorized as being in stage 2 meet the correct criteria for 3 of 5 questions in subtests one and two but do not meet these criteria in the next subtest. The percentage of students who are in stage 2 is 25.00%. This shows that only a small number of students are included in the stage 2 category.
4. Thinking Geometry Students Stage 3

At stage 3, students must meet the correct criteria for 3 of 5 questions in subtest 1, subtest 2, and subtest three but do not meet these criteria in the next subtest. Stage 3 is the stage where students are familiar with the shapes of the geometric fields, understand their properties, and can sort the shapes of the geometric planes that are related to each other. 3 is 6.94%. This shows that only a small number of students have entered stage 3 of van Hiele's geometric thinking, even though this stage 3 is a stage SMP/Madrasah Tsanawiyah students should have achieved.

5. Thinking Geometry Student Stage 4
   The deduction stage is the fourth stage in van Hiele's geometric thinking stage. Students at this stage meet the correct criteria for 3 of 5 questions in subtest 1, subtest 2, subtest 3, and subtest four but do not meet these criteria in the last subtest, subtest 5. At stage 4, students already understand the importance of definitions, axioms, postulates, and theorems and can conclude deductively. Based on the results of data analysis, it can be seen that the percentage of students who are in stage 4 is 0.00%. This shows that none of the students meet the van Hiele geometric thinking criteria at stage 4.
6. Thinking Geometry Students Stage 5
   Stage 5 is the last in van Hiele's geometric thinking stage. Students who are categorized as being at this stage are students who meet the correct criteria for 3 of 5 questions on all subtests (subtests 1-5). At this stage, students are expected to understand the importance of the accuracy of the basic principles that underlie a proof in geometry. Data analysis shows that the percentage of students in stage 5 is 0.00%. Like stage 4, this stage also showed that none of the students reached stage 5 in van Hiele's geometric thinking.
7. Thinking Geometry Student's "Jump Phenomenon"
   Students are said to be in the "jumping phenomenon" category if the student meets the criteria for correctly answering 3 of 5 questions in a particular subtest, but the student does not meet the criteria for correctly answering 3 of 5 questions in the previous subtests. Students in this category are whose van Hiele geometric thinking stage cannot be determined. This does not mean that students are below the introduction stage. These students meet the criteria at a particular stage but skip the previous stages. of 72 students. This number equals the number of students in stage 2 of van Hiele's geometric thinking. Many students cannot determine their van Hiele geometric thinking stage. There are six types of student answers that fall into the "jumping phenomenon" category. One of them is students who meet the criteria in subtest 4, which is 38.89% of the 18 students. The student skipped stages 1, 2, and 3, so they were not included in the van Hiele thinking stage category.

3.2. Discussion

Geometry is one of the branches of mathematics that has an excellent opportunity to be understood by students. However, in reality, many students still have difficulty understanding geometry material. This is probably caused by the learning process that is not adjusted to the level of ability possessed by students. Learning that does not pay attention to the level of student development will most likely result in students

experiencing difficulties because what is conveyed to students is not following students' abilities to understand the material presented.

To overcome these difficulties, the way that can be taken is the application of van Hiele's theory. According to van Hiele, a person will go through five stages of development in learning geometry, namely stages of visualization, analysis, informal deduction, deduction, and rigor. Students will pass these stages, and no stage can be skipped.

According to van de Walle [20], in learning geometry at school, if students are required to be ready to follow the high school geometry deduction curriculum, students need to progress to the informal deduction stage at the end of class VIII. Meanwhile, some research results show junior high school students have not yet progressed to the informal deduction stage. Research conducted by Safrina [19], Muhassanah [21], and Lestariyani [22] concluded that, in general, junior high school students have just reached the analysis stage. At the same time, Herlambang's [23] research showed that most junior high school students were in the visualization stage. From the explanation above, the researcher tried to examine the students' geometric thinking stage by doing a geometric thinking stage test developed based on van Hiele's geometric thinking stage indicators.

The test results were then analyzed to determine the students' geometric thinking stage. The results of the analysis of research data showed that MTs (Madrasah Tsanawiyah) An-Nur Cirebon students were in stage 1 (visualization), stage 2 (analysis), and stage 3 (informal deduction). Some students already know the shapes of the geometric field as a whole and understand the properties of the field. While at the informal deduction stage, only a small number of students can sort the shapes of the interconnected geometric planes. Students are said to be in stage 1 if they already know the geometric shapes as a whole. However, based on the researcher's findings, some students still cannot recognize some types of planes if their orientation (location) changes. Students cannot recognize triangles, rectangles, squares, and parallelograms when the sides of the plane are not on a vertical or horizontal line. This shows that students' learning experience in recognizing geometric shapes is still lacking, causing there are still students who have not reached stage 1 (visualization) of van Hiele's geometric thinking. The students who have not reached stage 1 are categorized into stage 0, which is the stage where students have not reached the van Hiele geometric thinking stage.

Comparing the number of students in stage 2 (analysis) is not much different from those in stage 1 (visualization). If you look at the results of students' answers, it can be seen that some students do not know and understand the properties of some geometric fields. The case that occurs is that most students think that the two diagonals of a rhombus have the same length. Some students also think that one side of an isosceles triangle must be twice as long as the other. This causes many students who have not reached stage 2 because students' understanding of the properties of the geometry field is still lacking.

The next stage is stage 3 (informal deduction) of van Hiele's geometric thinking. This stage is the highest van Hiele geometric thinking stage achieved by students so that none of the students can reach stage 4 (deduction) and stage 5 (rigor). Students in stage 3 must be able to see the relationship between one geometry field and another. Meanwhile,

based on the research results, although some students in stage 2 already know the properties of the geometry field, there are still very few students who can relate to these fields. Most students have not been able to see the relationship between two isosceles triangles, and students think that the corresponding angles of two triangles are not congruent. Students do not know the relationship between a square and a rectangle and think that a square cannot be called a rectangle. Some students even think that all the properties of rectangles are parallelograms. This proves that students' understanding of the relationships between geometric fields is still shallow, so very few students can reach this stage.

Not all students' geometric thinking abilities can be determined according to van Hiele's theory. This is one of the disadvantages of using the test method. Students who cannot determine their van Hiele geometric thinking stage can be said to be in the "jumping phenomenon" category. Most students who are in the "jumping phenomenon" category can reach stage 4 (deduction) of van Hiele's geometric thinking but skip the previous stages, namely stage 1 (visualization), stage 2 (analysis), and stage 3 (informal deduction). The student's thinking stage is not following the characteristics of van Hiele's geometric thinking stage, where students must go through the geometric thinking stage sequentially without passing a particular stage.

The comparison of van Hiele's geometric thinking stages that students can achieve is as follows:

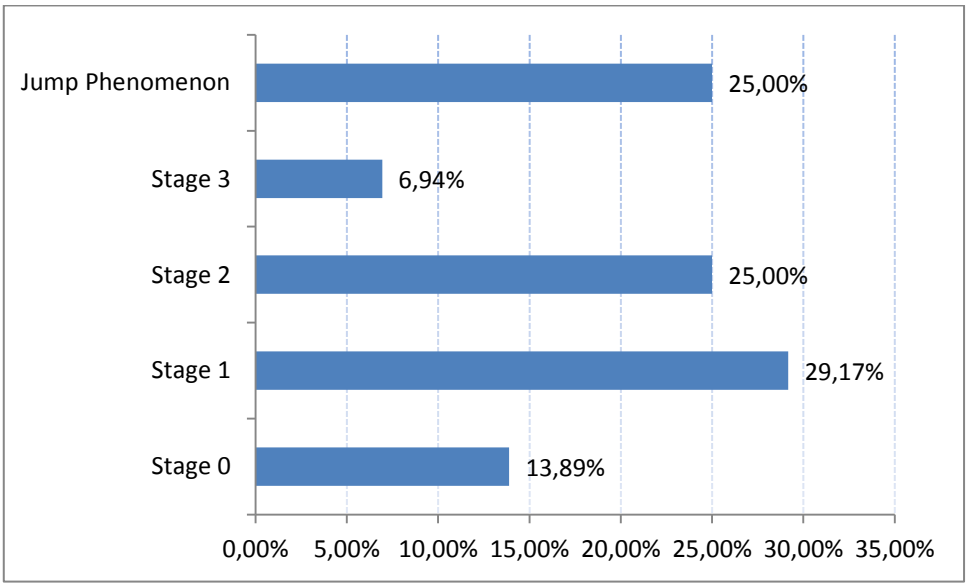

Figure 1. Graph of Van Hiele's Geometric Thinking Stage for MTs (Madrasah Tsanawiyah) An-Nur Cirebon Students

Figure 1 above shows that the students who can determine their van Hiele geometric thinking stage are 75.00%. Meanwhile, the students whose thinking stage of van Hiele geometry cannot be determined is 25.00%. The highest number of students is in stage 1 (visualization), which is 29.17%. These results differ from Lestariyani's [22] research, which states that the highest percentage of students is in stage 2 (analysis), which is

44.02%. This means there is a difference between the state of the subject studied by the researcher and the subject studied by Lestariyani [22].

Based on data analysis, it can be concluded that the van Hiele geometric thinking stage of MTs (Madrasah Tsanawiyah) An-Nur Cirebon students is in stages 1 (visualization) and 2 (analysis). These results indicate that the geometric thinking stage of junior high school students is not in line with the expectation that the geometric thinking stage of students should develop at the informal deduction stage. The factors that may be the cause of the geometric thinking stage of MTs (Madrasah Tsanawiyah) An-Nur Cirebon students have not been achieved, namely: the lack of geometry learning experience that students have and the geometry learning process in schools that is not adjusted to the student's ability level which results in students not being able to understand the geometry material presented.

To increase the geometric thinking stage of MTs (Madrasah Tsanawiyah) An-Nur Cirebon students to a higher level of thinking, the teacher can apply learning tailored to the level of student ability. One of them is by applying learning based on van Hiele's theory, which in learning activities will involve 5 phases [24], namely: the information phase (information), the direct orientation phase (Directed orientation), the explanation phase (explication), the free orientation, and integration phase.

4. CONCLUSION

Based on the results of research and data analysis on the geometric thinking stages of MTs (Madrasah Tsanawiyah) An-Nur Cirebon students based on van Hiele's theory, it is concluded that Overall, the students of MTs (Madrasah Tsanawiyah) An-Nur Cirebon City are in stage 1 (visualization), stage 2 (analysis), and stage 3 (informal deduction) in the van Hiele geometric thinking stage. The percentages respectively are 29.17% (stage 1), 25% (stage 2), and 6.94% (stage 3). The highest van Hiele geometric thinking stage achieved by MTs (Madrasah Tsanawiyah) An-Nur Cirebon students is stage 3 (informal deduction) so that none of the students can reach stage 4 (deduction) and stage 5 (rigor).

There are 13.89% of MTs (Madrasah Tsanawiyah) An-Nur students in Cirebon City who are categorized in stage 0, the stage where students are considered not to have entered the van Hiele geometric thinking stage. 25% of MTs (Madrasah Tsanawiyah) An-Nur students in Cirebon City are included in the "jumping phenomenon" category; this category is intended for students whose van Hiele geometric thinking stage cannot be determined. One of the weaknesses of using the test method is that some students cannot determine the stage of thinking in van Hiele's geometry.

In general, the van Hiele geometric thinking stage of MTs (Madrasah Tsanawiyah) An-Nur students in Cirebon City is stage 1 (visualization). This is not in line with the expectation that grade VIII junior high school students should develop at stage 3 (informal deduction). This means that students are still two levels lower than expected.

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