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Analysis of Grade VIII Students' Geometric Thinking Ability in Flat Surface Construction Material Based on Van Hiele's Theory

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Abstract. *Geometric thinking ability is a process carried out by students to obtain information, then from that information, they draw conclusions to solve problems related to geometry. The thinking process of each student is different and not always the same between one student and another. Therefore, to determine geometric thinking ability, we can look at the students' ability to pass through the stages of geometric thinking based on Van Hiele's Theory. These stages are level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). The subjects in this study were students in class VIII at Miftahul Ulum As-Sholchah Islamic Junior High School in Warungdowo, Pasuruan who had already learned the material on flat-sided shapes. There were three subjects who had geometric thinking abilities, and they were selected using purposive sampling. This study aims to explore the geometric thinking abilities of eighth-grade students in flat-sided spatial figures based on Van Hiele's Theory. The method used in this study is an exploratory qualitative research method with data collection techniques using tests and interviews. The results of this study indicate that the geometric thinking abilities of eighth-grade students in flat-sided solid geometry material based on Van Hiele's Theory are at level 0 (visualization), level 1 (analysis), level 2 (informal deduction), and level 3 (deduction), but none of the students are at level 4 (rigor).*

Keywords: *Geometric Thinking Ability, Flat-Sided Spatial Figures, Van Hiele Theory.*

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Introduction

Thinking is very important in mathematics. According to Ashar et al. (2021) thinking is a process that a person uses to remember and understand something. Meanwhile, Allsop (2019)state that thinking is a process carried out by students to obtain information, which is then used to find conclusions to solve problems related to geometry. This is in line with what was stated by that the thinking process of each student is different and not always the same between one student and another. Thus, in mathematics, thinking is a process of thinking with skills, freedom, and novelty in solving problems. According to Mawardi et al. (2023), in the 2013 curriculum revised in 2017, students are not only given formulas to solve problems, but they are also required to use their thinking skills to solve problems related to everyday life, one of which is geometry. In addition, in the learning process, for students to experience the thinking process, the role of educators is needed to help develop students' thinking processes.

Geometry is an important branch of mathematics. In line with what was stated by Simarmata et al. (2024), geometry is a part of mathematics that is closely related to other parts of mathematics. According to Pramudita & Rosnawati (2019), studying geometry has several objectives, namely, to provide more comprehensive knowledge; to develop problem-solving skills; to play an important role in learning other concepts in mathematics; to be applicable in everyday life for many people; and to be an enjoyable subject. However, in reality, students have only known geometry as memorization and application to problems, but they do not know the overall meaning of geometry. In fact, students have been learning geometry since elementary school. Therefore, students should have broader opportunities in learning geometry. Thus, there needs to be an appropriate strategy in the geometry learning process so that students can be interested and contribute to geometry learning to achieve a level of geometric thinking in students (Schweizer et al., 2012).

The theory often used in geometry learning is Van Hiele's Theory. According to Arnal-Bailera & Manero (2024) Van Hiele's Theory of Geometric Thinking is a theory of student thinking in learning geometry, whereby students cannot skip higher levels without passing through lower levels. This theory also explains the development of students' thinking in learning geometry. Thus, in learning geometry, students experience the development of thinking skills through certain stages. Meanwhile, according to Hartono et al. (2025), Van Hiele states that in learning geometry, students go through five stages, each of which describes the thinking process of students in geometry material. This is in line with what Fitriyani et al. (2018) stated, that in Van Hiele's Theory, students will go through five stages in learning and understanding geometry. The five stages are level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). Therefore, in order to move from one level of geometric thinking to the next, learning, especially geometry, needs to be adjusted between the learning experience and the students' level of thinking.

So far, there has been no research examining geometric thinking skills in flat-sided spatial figures from the perspective of Van Hiele's theory. Existing research have only discussed the difficulties students face in learning geometry. Based on the results of research by Aditya & Hiltrimartin (2024), it is stated that in geometry learning, junior high school students still memorize formulas but do not know the meaning of geometry and how to use it in solving problems because students do not understand the terms and symbols used in geometry problems. This shows that students have learned higher concepts but are not yet able to think maturely about basic things. In fact, junior high school students are expected to reach level 3 (deduction) of Van Hiele's Theory of Geometric Thinking. This is because, based on research conducted by Marchis (2012), if students do not reach level 3 (deduction) of Van Hiele's Theory of Geometric Thinking in junior high school, they will have difficulty learning geometry in high school. In contrast, the results of research by Sudirman et al. (2024) state that some junior high school students operate at level 2 (informal deduction) of Van Hiele's geometric thinking theory. Therefore, the researcher conducted this study entitled "Analysis of Grade VIII Students' Geometric Thinking Ability in Flat-Sided Solid Figures Based on Van Hiele's Theory."

Method

This study used a qualitative approach. This is in line with what Creswell (2012) stated that qualitative research is interpretive research in which the researcher is involved in a continuous and ongoing experience with the participants. The type of research used in this study was exploratory research. Exploratory research is research that aims to map an object in greater depth. In this study, exploratory research was used to explore the geometric thinking abilities of eighth-grade students on flat-sided shapes based on Van Hiele's Theory. The subjects in this study were eighth-grade students at MTs Miftahul Ulum As-Sholchah Warungdowo Pasuruan who had already learned the material on flat-sided shapes, consisting of three subjects who had geometric thinking abilities, using purposive sampling to select the subjects. Data collection techniques used tests and interviews. The instruments in this study were Van Hiele Theory geometric thinking ability test instruments consisting of five essay questions and interview guidelines that had been consulted with the supervising lecturer and validated by expert validators.

The Van Hiele Theory indicators of geometric thinking ability used in this study include: indicators at level 0 (visualization), namely that students can identify flat-sided shapes based on the shapes they see as a whole, students can determine examples and non-examples of flat-sided shapes, and students can draw or copy flat-sided shapes and identify parts of the shapes; indicators at level 1 (analysis), namely that students can describe flat-sided shapes based on their properties, students can compare flat-sided shapes with other flat-sided shapes based on their properties, and students can solve problems by involving the properties of flat-sided shapes that they have recognized; Indicators at level 2 (informal deduction) are that students can formulate definitions of flat-sided shapes based on the properties of flat-sided shapes, students can provide explanations regarding the relationships between flat-sided shapes; indicators at level 3 (deduction) are that students can understand several statements such as definitions, axioms, theorems, and proofs, and students can compile deductive proofs; and indicators at level 4 (rigor) are that students can understand the existence of axioms as basic statements that can be used to prove the truth in a theorem and students can compile proofs of theorems in flat-sided shapes.

In a study, it is necessary to check the validity of the data. The implementation of checking techniques is based on a number of specific criteria. There are four criteria used in data validity checking techniques in qualitative research, namely credibility, transferability, dependability, and confirmability. In this study, the data validity checking technique used is credibility. Furthermore, data credibility verification techniques can be implemented through extended participation, persistent observation, triangulation, peer checking, referential adequacy, negative case studies, and member checking. In this study, the data credibility verification technique used was triangulation. Triangulation is a data validity verification technique that utilizes other sources, and the most widely used triangulation technique is verification through other sources.

In this study, method triangulation was carried out by comparing the results of the Van Hiele Theory geometric thinking ability test with the interview results, and there was consistency between the two results, thus obtaining valid data that could be used in data analysis. After all the data has been collected, the next step is to analyze the data. In this study, data analysis was based on Miles and Huberman's model theory. Data analysis was carried out in three stages, as follows:

a. Data reduction

   Data reduction involves summarizing and selecting key points, focusing on important matters, and looking for patterns and themes. The data obtained is described in the form of a detailed description or report. This report must be analyzed from the outset to avoid difficulties at the end if the analysis is delayed. The report should focus only on important matters. The stages of data reduction in this study are as follows: Determine the research subjects, namely 3 students, then give them a test on geometric thinking skills in flat-sided shapes based on Van Hiele's Theory; Correcting the results of the geometric thinking ability test in the subject of flat-sided shapes as viewed from Van Hiele's Theory for the 3 students who had been determined; then analyzing the data results.

b. Data display

   Data presentations present data in the form of brief descriptions, pictures, graphs, and tables so that the overall picture and certain parts of this study can be seen clearly. The purpose is to better master the data and make it easier to read. Through this presentation, the data will be organized and neatly arranged, so that it is easy to understand. At this stage, the researcher presents the results of the research subjects' work. Data presentation aims to provide the possibility of a conclusion.

c. Conclusion drawing/verification

   Conclusion drawing/verification is the final step of this model, which is drawing conclusions and verification. The data that has been presented will be analyzed and compared based on the indicators of geometric thinking ability in Van Hiele's theory. The illustration of data analysis is shown in Figure 1.

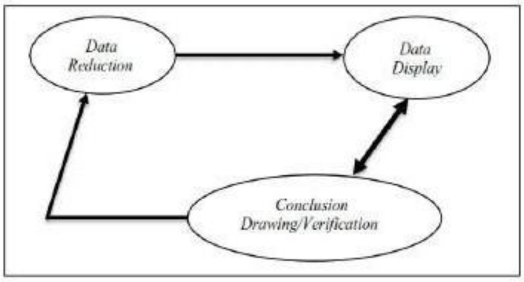

Figure 1. Data Analysis Stages

Results and Discussion

Based on the purposive sampling technique used to select subjects from eighth-grade students at MTs Miftahul Ulum As-Sholchah Warungdowo Pasuruan, three subjects were selected to take the Van Hiele Theory geometric thinking ability test and be interviewed. The subjects to be studied are shown in Table 1.

Table 1. Research Subject

Grade	Initial	Score Assignment	Assignment Score	Exam Daily 1	Exam Daily 2
VIII A	S1	100	95	95	95
VIII B	S2	100	100	95	95
VIII C	S3	95	100	90	95

1. **Presentation of Data on Van Hiele Theory Geometric Thinking Ability Test on Question Number 1**

The data presentation of the Van Hiele Theory geometric thinking ability test on question number 1 is as follows.

Figure 2. Students' Answer for The First Problem

Based on Figure 2, S1, S2, and S3 have achieved level 2 in the Van Hiele Theory of geometric thinking ability indicators. The initial step taken by S1, S2, and S3 was to name the flat-sided shapes according to the pictures in question number 1. S1, S2, and S3 were able to name the flat-sided shapes according to the pictures in questions 1a, 1b, and 1c, as shown in Figure 2. In this step, S1, S2, and S3 met the Van Hiele Theory geometric thinking ability indicator at level 0 (visualization), which is being able to identify flat-sided shapes based on the shape they see as a whole. The next step is for S1, S2, and S3 to be able to explain other properties or criteria according to the images of flat-sided shapes that have been named. S1, S2 and S3 are able to explain other properties or criteria according to the images of flat-sided shapes that have been named in questions 1a, 1b, and 1c, as shown in Figure 2. In this step, S1, S2 and S3 meet the Van Hiele Theory geometric thinking ability indicator at level 1 (analysis), which is being able to describe flat-sided shapes based on their properties. The final step performed by S1, S2 and S3 is to group the flat-sided shapes according to the instructions in the question. S1, S2 and S3 are able to group the flat-sided shapes according to the instructions in questions 1a, 1b, and 1c, as shown in Figure 2. In this step, S1, S2, and S3 met the Van Hiele Theory geometric thinking ability indicator at level 2 (informal deduction), which is being able to explain the relationships between flat-sided shapes.

2. **Presentation of Data on Van Hiele's Theory of Geometric Thinking Ability Test on Question Number 2**

The presentation of data on the Van Hiele Theory geometric thinking ability test for question number 2 is as follows.

Figure 3. Students' Answer for The Second Problem

Based on Figure 3, S1, S2, and S3 have achieved level 1 of Van Hiele's geometric thinking ability indicators. The initial step taken by S3 was to name the flat-sided shapes according to the picture in question number 2. S1, S2, and S3 were able to name the flat-sided shapes according to the pictures in questions 2a, 2b, and 2c, as shown in Figure 3. In this step, S1, S2 and S3 met the Van Hiele Theory geometric thinking ability indicator at level 0 (visualization), which is being able to identify flat-sided shapes based on the shape they see as a whole. The next step is for S1, S2, and S3 to be able to explain other properties or criteria according to the images of flat-sided shapes that have been named. S1, S2, and S3 are able to explain other properties or criteria according to the images of flat-sided shapes that have been named in questions 2a, 2b, and 2c, as shown in Figure 3. In this step, S1, S2, and S3 meet the Van Hiele Theory geometric thinking ability indicator at level 1 (analysis), which is being able to describe flat-sided shapes based on their properties.

3. Presentation of Van Hiele Theory Geometric Thinking Ability Test Data on Question Number 3

The presentation of data on the Van Hiele Theory geometric thinking ability test in question number 3 is as follows.

Figure 4. Students' Answer for The Third Problem

Based on Figure 4, S1, S2, and S3 have demonstrated the Van Hiele geometric thinking ability indicator at level 2. S1, S2, and S3 were able to correctly solve question number 3. The steps taken by S1, S2, and S3 were to explain the similarities and differences between flat-sided shapes according to the instructions in the question based on the relevant relationships and properties of flat-sided shapes. S1, S2, and S3 were able to explain the similarities and differences between flat-sided shapes according to the instructions in the question based on the relevant relationships and properties of flat-sided shapes with the instructions in questions 3a, 3b, 3c, 3d and 3e, as shown in Figure 4. In this step, S1, S2, and S3 meet the Van Hiele Theory geometric thinking ability indicator at level 2 (informal deduction), which is being able to provide an explanation of the related relationships between flat-sided shapes.

4. **Presentation of Data on Van Hiele's Theory of Geometric Thinking Ability Test in Question Number 4**

The data presentation of the Van Hiele Theory geometric thinking ability test on question number 4 is as follows.

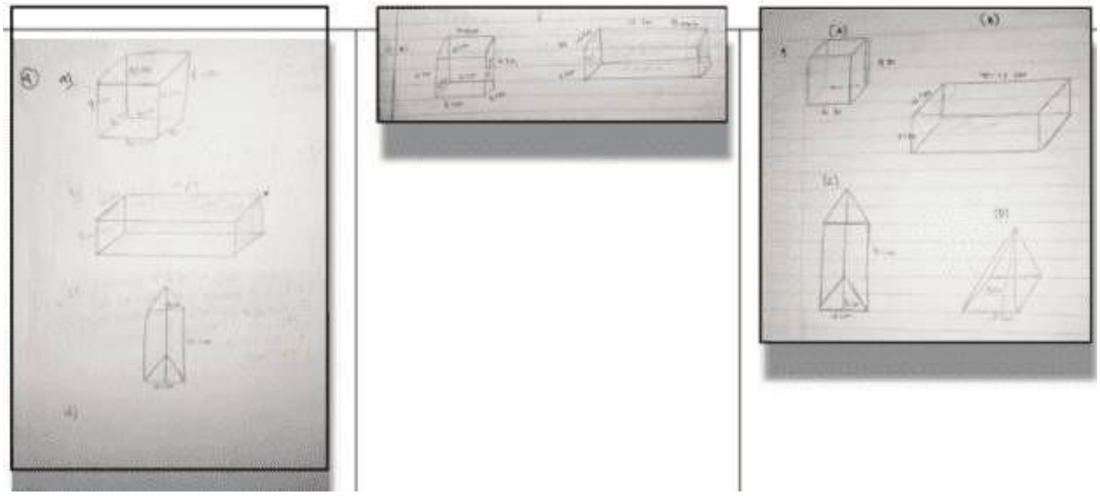

Figure 5. Students' Answer for The Fourth Problem

Based on Figure 4, S1, S2, and S3 have achieved level 3 of Van Hiele's geometric thinking ability indicator. S1, S2, and S3 can solve and understand several definitions, axioms, theorems, and proofs, and can correctly construct deductive proofs for question number 4. The steps taken by S1, S2, and S3 were to draw flat-sided shapes according to the information provided in question number 4, namely the definitions, theorems, and proofs using the flat-sided shape formulas provided in the question so that they could draw sketches according to the instructions in question number 4. However, S1 could only answer questions 4a, 4b, and 4c but could not answer question 4d, as shown in Figure 5a, S1's answer. Meanwhile, S2 could only answer questions 4a and 4b but could not answer questions 4c and 4d, as shown in Figure 5b, S2's answer. In contrast, S3 was able to answer questions 4a, 4b, 4c, and 4d, as shown in Figure 5c of S3's answers. At this stage, S1, S2, and S3 meet the Van Hiele Theory geometric thinking ability indicator at level 3 (deduction), which is the ability to understand several definitions, axioms, theorems, and proofs, as well as the ability to construct deductive proofs on flat-sided shapes.

5. Presentation of Data on Van Hiele's Theory of Geometric Thinking Ability Test on Question Number 5

The presentation of data on the Van Hiele Theory geometric thinking ability test for question number 5 is as follows.

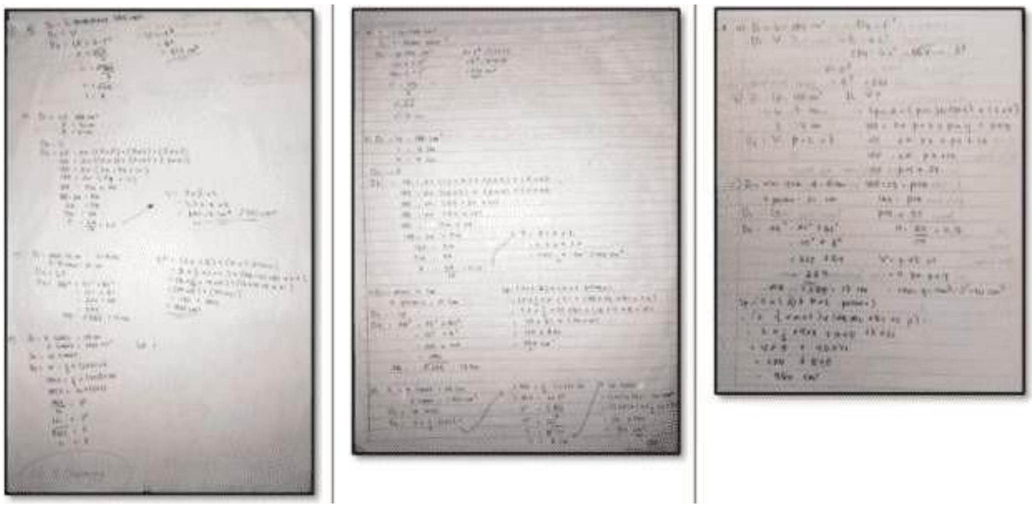

Figure 6. Students' Answer for The Fifth Problem

Based on Figure 6, S1, S2, and S3 have achieved level 3 of Van Hiele's geometric thinking ability indicator. S1, S2, and S3 can solve and understand several definitions, axioms, theorems, and proofs, and are able to deduce the proofs of flat-sided geometric formulas correctly in question number 5. The steps taken by S1, S2, and S3 were to solve question number 5 by using the definitions and theorems of flat-sided shapes in accordance with the information given in question number 5, namely the definitions, theorems, and proofs using the known formulas for flat-sided shapes in the question, so that they could solve the question correctly in accordance with the instructions in question number 5. However, S1 was unable to complete question number 5d, as shown in Figure 5a of S1's answers. In addition, in question number 5b, S1 made a slight mistake in writing the formula for the surface area of a block, resulting in an incorrect final calculation for question number 5b. Meanwhile, S2 was able to complete questions 5a, 5b, 5c and 5d, as shown in Figure 6b of S2's answers. In addition, in question 5b, S2 made a slight mistake in writing the formula for the surface area of a block, resulting in an incorrect final calculation for question 5b. S3 could not complete question number 5d, as shown in Figure 6c of S3's answers. In addition, in question number 5b, S3 made a slight error in writing the formula for the surface area of a block, resulting in an incorrect final calculation for question number 5b. In this step, S1, S2, and S3 meet the Van Hiele Theory geometric thinking ability indicator at level 3 (deduction), which is being able to understand several definitions, axioms, theorems, and proofs and being able to construct deductive proofs on flat-sided shapes.

Based on the presentation of data and analysis of the results of research on geometric thinking ability in flat-sided shapes reviewed from Van Hiele's Theory, the overall discussion of students' geometric thinking ability reviewed from Van Hiele's Theory can be summarized as follows.

1. Geometric Thinking Ability According to Van Hiele Theory Subject 1 (S1)

According to the test results and interview results with S1, he/she understood questions 1 to 5. In question 1, S1 was able to name the flat-sided shapes according to the pictures. This is in line with the research by Fitriyani et al. (2018) that students at level 0 (visualization) have been able to pass visualization, but students have not been able to move on to the next level, namely level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). Furthermore, in question number 2, S1 was able to explain other properties or criteria according to the image of flat-sided shapes that had been named. This is in line with the research by Fitriyani et al. (2018) that students at level 1 (analysis) can explore the properties or characteristics of the images presented in the questions. In question number 3, S1 is able to explain the similarities and differences between flat-sided shapes according to the instructions in the question based on the relationships and properties of flat-sided shapes with the instructions in the question. This is in line with the research by Fitriyani et al. (2018) that students at level 2 (informal deduction) can identify the relationships between flat-sided shapes. S1 is also able to solve and understand several definitions, axioms, theorems, and proofs, and can correctly construct deductive proofs of flat-sided shapes in questions 4 and 5. This is in line with the research by Fitriyani et al. (2018) that students at level 3 (deduction) are able to prove formulas for flat-sided shapes.

However, S1 is still unable to reach level 4 (rigor). This is in line with the research by Arnal-Bailera & Manero (2024) that at level 4 (rigor), students can only guess the results of solving problems by knowing the formula and substituting numbers into the formula for flat-sided shapes. This can be seen from the test answers and S1's interview results on questions 4 and 5. On question 4, S1 was only able to answer questions 4a, 4b, and 4c but was unable to answer question 4d. In addition, in question number 5, S1 could not complete question 5d, and in question number 5b, there was a slight error in writing the formula for the surface area of a block, which resulted in an incorrect final calculation for question number 5b. According to Hartono et al. (2025), no students were able to pass level 4 (rigor), but the students who will continue to level 4 (rigor) have passed the previous levels, namely level 0 (visualization), level 1 (analysis), level 2 (informal deduction), and level 3 (deduction). This is in line with what Fitriyani et al. (2018) stated, namely that if students do not reach level 3 (deduction) of Van Hiele's geometric thinking theory in junior high school, they will have difficulty learning geometry in high school.

2. Van Hiele Geometric Thinking Ability of Subject 2 (S2)

According to the test results and interview results, S2 understood questions 1 to 5. In question 1, S2 was able to name the flat-sided shapes according to the pictures. This is in line with the research by Arnal-Bailera & Manero (2024) that students at level 0 (visualization) have been able to pass visualization, but students have not been able to move on to the next level, namely level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). Furthermore, in question number 2, S1 is able to explain other properties or criteria according to the image of flat sided shapes that have been named. This is in line with the research by Fitriyani et al. (2018) that students at level 1 (analysis) can explore the properties or characteristics of the images presented in the questions. In question number 3, S2 is able to explain the similarities and differences between flat-sided shapes according to the instructions in the question based on the relationships and properties of flat-sided shapes with the instructions in the question. This is in line with the research by Fitriyani et al. (2018) that students at level 2 (informal deduction) can identify the relationships between flat-sided shapes. S2 is also able to solve and understand several definitions, axioms, theorems, and proofs, as well as deduce the formulas for flat-sided shapes correctly in questions 4 and 5. This is in line with the research by Fitriyani et al. (2018) that students at level 3 (deduction) are able to prove formulas for flat-sided shapes.

However, S2 is still unable to reach level 4 (rigor). This is in line with the research by Sudirman et al. (2024) that at level 4 (rigor), students can only guess the results of solving problems by knowing the formula and substituting numbers into the formula for flat-sided shapes. This can be seen from the test answers and the results of the S2 interview on question number 4. On question number 4, S2 was only able to answer questions 4a and 4b but could not answer questions 4c and 4d. In addition, on question number 5b, there was a slight error in writing the formula for the surface area of a block, which resulted in an incorrect final calculation for question number 5b. According to Faradiba et al. (2024), no students were able to pass level 4 (rigor), but the students who will continue to level 4 (rigor) have passed the previous levels, namely level 0 (visualization), level 1 (analysis), level 2 (informal deduction), and level 3 (deduction). This is in line with what was stated by Faradiba & Alifiani (2020), who stated that if students do not reach level 3 (deduction) of Van Hiele's geometric thinking theory in junior high school, they will have difficulty learning geometry in high school.

3. Van Hiele Geometric Thinking Ability of Subject 3 (S3)

According to the test results and interview results, S3 understood questions 1 to 5. In question 1, S3 was able to name the flat-sided shapes according to the pictures. This is in line with the research by Maliana et al. (2025) that students at level 0 (visualization) have been able to pass visualization, but students have not been able to move on to the next level, namely level

1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). Furthermore, in question number 2, S3 can explain other properties or criteria according to the image of flatsided shapes that have been named. This is in line with the research by Rohmah et al. (2025) that students at level 1 (analysis) can explore the properties or characteristics of the images presented in the questions. In question number 3, S3 is able to explain the similarities and differences between flat-sided shapes according to the instructions in the question based on the relationships and properties of flat-sided shapes with the instructions in the question. This is in line with the research by Wardhana et al. (2025) that students at level 2 (informal deduction) are able to identify the relationships between flat-sided shapes. S3 is also able to solve and understand several definitions, axioms, theorems, and proofs, and can correctly construct deductive proofs of flat-sided shapes in questions 4 and 5. This is in line with the research by Isminingsih et al. (2025) that students at level 3 (deduction) are able to prove formulas for flatsided shapes. However, S3 is still unable to reach level 4 (rigor). This is in line with the research by Novak & Tassell (2017) that at level 4 (rigor), students can only guess the results of solving the problem by knowing the formula and substituting numbers into the flat-sided spatial figure formula. This can be seen from the test answers and the results of the S3 interviews on question number 5. In question number 5, S3 could not answer question 5d, and in question number 5b, there was a slight error in writing the formula for the surface area of a block, which made the final calculation for question number 5b incorrect. According to Chen & Ja'Faruddin (2021), no students were able to pass level 4 (rigor), but students who will continue to level 4 (rigor) have passed the previous levels, namely level 0 (visualization), level 1 (analysis), level 2 (informal deduction), and level 3 (deduction). This is in line with what Hsueh et al. (2019) stated, that if students do not reach level 3 (deduction) of Van Hiele's geometric thinking theory in junior high school, then students will have difficulty in learning geometry in high school.

Conclusion

Based on the results of data analysis, no subject was able to pass level 4 (rigor), but the results of the study showed that the subjects were able to pass the previous levels, namely level 0 (visualization), level 1 (analysis), level 2 (informal deduction), and level 3 (deduction). Each subject had different Van Hiele geometric thinking abilities in answering the questions given by the researcher. All three subjects were able to perform level 0 (visualization) indicators, namely being able to name flat-sided shapes according to the pictures. The three subjects were able to carry out level 1 (analysis) indicators, namely being able to explain other properties or criteria in accordance with the images of flat-sided shapes that had been named. All three subjects were able to perform level 2 (informal deduction) indicators, namely explaining the similarities and differences between flat-sided shapes according to the instructions in the questions based on the relevant relationships and properties of flat-sided shapes. All three subjects were able to perform level 3 indicators (deduction), namely being able to complete and understand several statements of definitions, axioms, theorems, and proofs, as well as being able to compile deductive proofs in the questions. However, the subjects were still unable to reach level 4 (rigor). The subjects could only guess the results of the questions by knowing the formulas and substituting numbers into the flat-sided shapes formulas. This can be seen from the test results and the results of the subject interviews on questions 4 and 5. In questions 4 and 5, the subjects could not complete all the questions, but only a few.

The suggestions in this study are as follows: 1) Educators are advised to encourage students to further develop their geometric thinking skills in learning geometry by providing many geometry exercises so that they can see the students' ability to master the material being taught. Educators can also provide material in accordance with the stages of Van Hiele's geometric thinking theory so that students can understand geometry, starting from an introduction to basic material to complex material; 2) it is recommended that students get used to understanding the material, understanding the meaning of the questions, and doing more practice questions in various question models, as well as being careful in answering the questions; 3) For future researchers, it is recommended to develop research on different subjects and materials to further improve the shortcomings in this study.

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