The Effectiveness of Geometry Learning Tools in Increasing the Level of Thinking of Junior High School Students

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Abstract: This study aims to obtain a learning device for junior high school geometry based on Van Hiele's theory to improve students' thinking levels from the level of analysis to the level of informal deduction. The researcher uses the Four D-Model development method which consists of several stages, namely: define, design, develop; and (d) disseminate. The definition stage includes examining student characteristics, reviewing curriculum content, and analyzing tasks and learning objectives. The draft I of the learning tool was made at the design stage based on the results of the define stage. This draft consists of a Lesson Plan, Student Books, Student Worksheets, and an evaluation instrument. Then in the develo stage, the activities carried out were to validate Draft I and test the readability of Draft I (trial I). These results were used to revise Draft I and produce Draft II. At this development stage, a second trial of Draft II was also carried out. Trial II was used to determine the practicality and effectiveness of the resulting learning tools. The results of the development of these learning tools are a set of junior high school geometry learning tools based on Van Hiele's theory, namely Student Books, Lesson Plans, Student Worksheets, and evaluation instruments that can improve students' thinking levels from the analysis level to the informal deduction level. This learning tool is needed by teachers in remedial learning to improve students' thinking from level 1 to level 2.

1 INTRODUCTION

Geometry is a mathematical part that discusses the concept of mathematics related to planes and spaces. One of the basic goals of teaching mathematics is to improve the students' geometric thinking levels (Al-ebous, 2016). Having Al-Ebous also argues that geometry is one of the materials in the mathematics curriculum that can develop spatial abilities and reasoning (Al-ebous, 2016). According to the theory of Van Hiele that someone in learning geometry must go through five levels of thinking that are hierarchical. The fifth levels are visualization, analysis, informal deduction, deduction, and rigor (Erdogan, 2020). Crowley explained the five levels of thinking as follows: Level 0 (visualization), students only understand the geometric form of objects but do not understand the parts of the geometry object component; Level 1 (analysis), students can recognize different forms of geometry and their properties, but not yet understand the relationship of the properties of the forms of geometry; Level 2 (informal deductive), at this stage students can identify and classify the properties of geometry and use the relationship between the properties of geometry; Level 3 (deductive), at this stage students can make more meaningful geometry forms and can construct logical evidence; and level 4 (rigor), at this stage students can understand the axiomatic system in a geometry system and be able to verify the impact of the axiomatic system. The five stages of thinking this is hierarchical and sequential (Moru et al., 2020). It means that a student who learns geometry is expected to increase their level of thinking as the level rises. According to the theory of cognitive development from Piaget, ideally, the levels of thinking of junior

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high school students in learning geometry have reached the level of informal deduction, although the axiomatic system has also been introduced. Based on several research results (Luneta, 2015)(Fuys et al., 1988)(Clements & Battista, 1992) found students in learning geometry are still in level 0 and level 1. This indicates that geometry learning at the junior high level needs serious attention. According to Van Hiele, the level of thinking students in learning geometry from a certain level can be increased to the next level depending on the learning experience (Kusuma et al., 2021). This means that the increase in the level of thinking students is influenced by the design of learning. Middle school geometry learning tools that aim to increase the student thinking level of a certain level to the next level based on Van Hiele's theory is still very lacking. Though these tools are needed to help students understand higher geometry concepts.

Characteristics of the concept of geometry is abstract and hierarchical. This means that to understand the C concept is needed a good understanding of the concept of A and B. Because all concepts in the mathematical system include mutually related geometry and hierarchical. For this reason, the ability to think about the characteristics of the concept are learned. In the 2013 Mathematics Curriculum, it has presented junior high school geometry teaching materials about the concepts of two parallel lines cut by tranversal lines and their applications in proving the theorem that is simple. For example, prove: "The number of sizes of the corners of a triangel is 180^0".

To prove the theorem, students must be able to understand the relationship between traits in the concept of two parallel lines cut by transverse lines. This shows that students in learning the concept of geometry is expected to have achieved a full stage of thinking 2 (informal deductive) and thinking phase 3 (formal deduction) although relatively simple. Thus, both based on Piaget's theory and the characteristics of junior high school teaching materials turned out to be the level of thinking of junior high school students in learning geometry is expected to have reached the level of thinking 2 and the thinking level 3. Based on this and the results of the research described above that most of the junior high school students in learning geometry are still in level 0 and level 1, it is deemed necessary to have a geometry learning tool to increase the student thinking level from level 1 to level 2. Based on the study of several references, researchers have not found research results that produce special learning tools like this. This learning tool is specifically used for remedial purposes in small groups. This learning tool is designed on a constructivist basis, so that the geometric concepts learned are more meaningful. Therefore this study aims to develop Junior Geometry Learning Tools based on Hiele's theory of Van to increase the student thinking level of the analysis level to the informal deduction level through a development research.

2 METHOD

This research is a development and research. Things to note in development research are the quality of products produced. Plomp and Nieveen provide product quality criteria namely valid (reflecting the state-of-the art and consistent internal assessment), have added value, practical and effective (Palupi & Khabibah, 2018)(Nieveen, 1999). The product is said to be valid if the material components are based on state-of the art knowledge (validation of content) and all components are consistently related (construct validation). The product is said to be of practical quality if according to other teachers or experts are useful and easy to implement by teachers and students.

Categorized as effective, if it reflects student experience and expected student learning outcomes. Therefore the focus of this development research is a quality product produced by valid, practical and effective criteria. This learning tool is said to be valid, if the validator has declared it as such and feasible to use, even though there is a revision. This learning tool can be declared to meet practical criteria, if the respondent (user) of the learning device tends to provide a positive response. This learning device can be declared effective, if it can increase the student thinking level of the analysis level to the level of informal deduction. The learning tool development model used in this study is the Four D-Model proposed by Thiagarajan and Semmel (Thiagarajan, 1974), namely (a) the definition stage, (b) the design stage, (c) the development stage and (d) the stage of dissemination. The activities carried out at the definition stage are examining the content of junior high school geometry in the curriculum and the characteristics of students in geometric thinking. While the activities at the design stage are compiling and making learning tools based on the results of activities at the defining stage. The results of the activities at the design stage are in the form of an initial prototype (Draft I) of learning tools. The next activity at the development stage is to carry out trial I and trial II. Trial I to determine the readability of Draft I and trial II to determine the effectiveness of

the learning tools developed. The results of the development in the first trial resulted in Draft II. Then this Draft II was developed in the second trial and resulted in a final draft that met the specified criteria. The data in this study are quantitative and qualitative. The data collection techniques used in this study consisted of (a) Van Hiele Geometry Test (VHGT) developed by Usiskin (Usiskin, 1982). This test is used to classify students' thinking stages in understanding geometric concepts; (b) Interview. Test-based interview activities (VHGT) to confirm the data obtained from the test results (VHGT); (c) The researcher used a questionnaire to obtain data on student responses in writing to test the practicality of the learning tools developed. Data analysis in this study used descriptive data analysis. Meanwhile, specifically for qualitative data, it refers to the qualitative data analysis of the Miles and Huberman model, namely: data reduction, data display and conclusions/verification.

3 RESULTS OF RESEARCH

The results of the development of these learning tools are as follows:

3.1 Results of the Defined Phase

The results that the researchers obtained at this stage were: (a) the results of the study of curriculum content and mathematics textbooks for grade 7 semester 2 for the 2013 Curriculum, showed that the description of the concept material for the types of rectangles was not detailed and did not comprehensively explain the relationship between the properties of the types of rectangles and how to define each type of quadrilateral; (b) the results of the survey and initial test of the trial development of this learning tools at SMPN 12 Palu from 15 students tested, which yields the results of 14 students in the visualization level of thinking, 4 students in the analytical thinking level and 1 student in the informal deduction level. This shows that learning geometry at the junior high school level needs attention. According to Piaget's theory of cognitive development, junior high school students in learning geometry should have reached the level of informal analysis and deduction thinking; (c) the geometric concepts obtained from the concept analysis are the concept of the types of quadrilaterals regarding their properties, the relationship between the properties of the types of quadrilaterals and the definition of the types of quadrilaterals. The types of quadrilaterals are parallelogram, rectangle, square, rhombus, kite, and trapezoid; (d) the results of the task analysis developed are Student Worksheets and independent assignments contained in the Student Book; (e) the learning objectives to be achieved are as follows: determine the properties of each type of quadrilateral; determine the relationship between certain types of quadrilaterals and other types of rectangles; define the concept of a certain type of quadrilateral based on its properties.

3.2 Results of the Design Phase

The result of development at this design stage is called Draft I or the initial prototype. This initial prototype is packaged in Student Books, Lesson Plans, Practice Questions, and Student Worksheets. The Student's Book contains teaching materials for quadrilaterals, especially the properties of types of rectangles, the relationship between the properties of types of rectangles, and definitions of types of rectangles. The material on the types of rectangles contained in the Student Book includes parallelograms, rectangles, squares, rhombuses, kites, and trapezoids. These teaching materials are presented or packaged on constructivist grounds. This means that the properties of the types of quadrilaterals, the relationship between the properties of the types of rectangles, and the definition of each type of quadrilateral that students must learn are expected to be found by students themselves. Meanwhile, the steps of the Lesson Plan are packaged based on the syntax of the Van Hiele learning model which consists of five phases, namely: (a) the information phase; (b) the directional orientation phase; (c) the affirmation phase; (d) free orientation phase and; (e) integration phase. The design of this learning tool is based on Van Hiele's theory, namely the theory of thinking levels and Van Hiele's learning model.

The characteristics of this learning tool are specifically to improve the thinking level of junior high school students in learning geometry from the analysis level to the informal deduction level. While the teaching materials include rectangular shapes. The quadrilaterals in question are parallelograms, rectangles, squares, rhombuses, kites, and trapezoids.

3.3 Results of the Develop Phase

At this development stage, three things are produced, namely: (a) validation results from the validator; (b) the results of trial I (readability test), and; (c) the results of the second trial (effectiveness test and practicality test). Based on the results of the

development at the design stage, it was then validated by two mathematics lecturers teaching geometry and three junior high schools.

Table 1: Validation Results.

No.	Analyzed Area	Average Validator Rating				Average
		Student Book	Worksheet	Lesson Plans	Practice Questions	
1	Contents	3.40	3.70	3.47	3.60	3.54
2	Construction	3.50	3.50	3.60	3.70	3.58
3	Language	3.60	3.70	3.60	3.60	3.63
Total		10.50	10.90	10.67	10.90	10.75
Average		3.50	3.63	3.56	3.63	3.58
Conclusion		Valid	valid	valid	valid	Valid

Based on Table 1 above, it turns out that all the learning tools developed meet the valid criteria, although there are still revisions and the revision results produce an initial prototype (Draft I). Meanwhile, in the first trial results, several words/terms and sentences were found in the Student Book and Student Worksheets that needed to be revised. The results of this revision resulted in Draft II. Then this Draft II was tested (trial II) on class IIB students of SMPN 12 Palu. This second trial, involved four test subjects whose thinking level was at the analysis level, namely IT subjects, AZ subjects, MA subjects, and EP subjects. Trial II was carried out for five meetings of learning activities. The results of this second trial are listed in Table 2 below.

Table 2: Final test results in trial II.

No	Trial Subject	Number of Correct Answers for Each Question			Level Category
		1-5	6-10	11-15	
1	IT	3	2	2	Level 2
2	AZ	3	1	0	Level 1
3	MA	3	1	2	Level 2
4	EP	3	1	1	Level 2

After triangulating the method with interviews, the results remained the same as in Table 2 above. Thus, it can be concluded that the developed learning tools can improve the subject's thinking level from level 1 (analysis) to level 2 (informal deduction), although one subject (subject AZ) is still at the analysis level. Furthermore, the practicality test of using the resulting product (learning tool) is shown in Table 3 below.

Table 3: Student responses to the application of learning tools during trial II.

No.	Statements in the questionnaire responded by the students	∑	
1	Presentation of material in Student Books and Student Worksheets is interesting	19	
2	Presentation of material in the Worksheet Students can find the concept being studied.	19	
3	The content of the Student Worksheet is in accordance with the Student Book	19	
4	The teaching method used by the teacher is fun and interesting.	19	
5	The learning method used by the teacher can raise students' interest in learning.	19	
6	The learning method used by the teacher can improve understanding of the concepts being studied.	19	
7	Learning process activities can improve thinking skills.	19	
8	Learning process activities increase the attitude of respect and cooperation in groups.	19	
9	The language in the Student Books, Student Worksheets and Practice Questions is understandable.	19	
10	The questions in the Problem Practice challenge the thinking process.	19	
Total		190	
Percentage (%)		100.00	
Total Percentage of Positive/Negative criteria (%)		(Positive) 0.94	(Negative) 19.05
Number of Students Filling Out Questionnaire		19	

Based on Table 3 above, in general, the students' responses to the learning tools and processes during the second trial obtained the average student response in the positive category reaching 19.05% and in the negative category reaching 0.95%. This shows that the learning tool meets the criteria of practicality. Thus, it can be concluded that the SMP geometry learning tools, especially the quadrilaterals that have been developed, have met the valid, practical and effective criteria. The dissemination stage for the

development of learning tools is carried out at this seminar and positive suggestions are highly expected.

4 DISCUSSION OF RESEARCH RESULTS

At the stage of defining the development of these learning tools, especially the results of the analysis of the K-13 curriculum, it turns out that in the curriculum the content of the material does not explain the properties of the types of rectangles in detail and comprehensively. In the Mathematics Package Book for grade VII for K-13, there is also no correlation between the properties of the quadrilaterals; so students understand the concepts of quadrilateral types not comprehensively. As a result, students find it difficult to find interrelationships between concepts of the quadrilateral type. This is by the opinion of the researchers, that students are not accustomed to doing formal proofs in learning geometry at school, but more informal geometry learning is needed (Alex & Mammen, 2016). Therefore, it is necessary to present the material in an orderly, systematic, and comprehensive manner, so that students have complete knowledge and understanding of the types of quadrilaterals. For this reason, it is also necessary to have a concept map between the concepts of the types of quadrilaterals as a means for students to understand the properties and definitions of the concepts of the types of quadrilaterals.

Based on the results of the initial test, most of the students of SMPN 12 Palu in learning geometry 14 were at the visualization level, 4 students were at the analysis level and 1 person was at the informal deduction thinking level. According to intellectual development theory, junior high school students should be able to think formally. This means that students' understanding of geometric concepts should be more abstract and not at the visualization level. Students should be able to understand more abstract geometric concepts, whether presented in the form of definitions or theorems of the relationship between concepts. Therefore, based on the characteristics of students who are still in visualization thinking and the ideal competencies that junior high school students should have, it is appropriate that the development of this learning tool was developed through this research. According to intellectual development theory, junior high school students should be able to think formally. This means that students' understanding of geometric concepts should be more abstract and not at the visualization level. Students should be able to understand more abstract geometric concepts, whether presented in the form of definitions or theorems of the relationship between concepts. Therefore, based on the characteristics of students who are still in visualization thinking and the ideal competencies that junior high school students should have, it is appropriate that the development of this learning tool was developed through this research. According to De Villiers (Alex & Mammen, 2016), the revision of the curriculum on geometry material in elementary schools will determine the success of students in learning geometry in junior high schools.

Related to this, the design of learning tools developed, especially Student Books and Student Worksheets are designed with the aim of increasing students' thinking stages from the analysis level to the informal deduction level. Construction of Student Books and Student Worksheets on a constructivist basis. This means that the core concepts being studied can be found by students themselves through activities in learning.

At the development stage, the learning tools developed were validated by mathematics education lecturers and junior high school mathematics teachers. Aspects that are validated include aspects of material content, construction, and language aspects. The validation results show that the developed learning tools meet the valid criteria, although there are several revisions. Most of the revisions are related to language aspects, especially terms/words, and sentences. This is also related to the results of trial I, it turns out that there are terms/words or fragments of sentences that students do not understand, so revisions are needed. Then revisions were made and then the revised draft was tested in the second trial to determine the effectiveness of the developed learning tools. This is by Van Hiele's opinion that the language used in learning geometry is very important (Al-ebous, 2016). Therefore, the language factor in the form of writing, symbols or verbal in learning geometry greatly affects students' understanding of the concepts being taught.

The results of this second trial indicate that the learning tools developed meet the effective criteria. It is evident that the four experimental subjects experienced an increase in the thinking level from the analysis level to the informal deduction level, although there was one experimental subject that did not experience an increase in the thinking level. This shows that the learning tools developed are quite effective in increasing the thinking level of junior high school students in learning geometry from the analysis level to the informal deduction level. At the

transition level of thinking from the analysis level to the informal deduction level, conceptualization skills are needed. Some research results show that conceptualization is a cognitive process that is often experienced by students when solving problems (Noor & Alghadari, 2021)(Aghadari, 2021).

The weak mastery of geometric concepts experienced by students is due to the lack of student's ability to solve problems (Noviana & Hadi, 2021)(Aghadari, 2021). The low level of thinking ability of students is caused by the learning strategies used in schools. Therefore, learning geometry should place more emphasis on problem solving, reasoning and spatial abilities (Hassan et al., 2020)(Cahyanita et al., 2021). In addition, language also plays an important role in learning geometry. A teacher in teaching geometry must use language that is in accordance with the development of students' thinking (Pasani, 2019). Students at the abstraction thinking level have understood the concept definition well. This means that students have been able to understand the meaning of the definition, even though the representation is different from the definition presented formally. A student in constructing the meaning of a concept depends on his ability to understand the definition of the concept. Therefore, the role of definition is very important in constructing the meaning of a concept (Haj-Yahya, 2021).

The results of the practicality test of using learning tools also indicate a positive thing. Because most of the students' responses to learning tools in the second trial process were in the positive category with an average of 19.05% and only an average of 0.95% in the negative category. This means that students are quite good at responding to the learning tools used and it means that the learning tools developed meet the practical criteria.

Thus the geometry learning tool for junior high school level developed through this research has met the valid, practical, and effective criteria for improving students' thinking level from the analysis level to the informal deduction level.

5 CONCLUSION

Based on the results of this development research, a geometry learning device for junior high school level based on Van Hiele's theory has been obtained which can improve students' thinking levels from the analysis level to the informal deduction level. These learning tools are Student Books, Lesson Plans, Student Worksheets, and Practice Questions. The specifications of this learning tool are as follows: (a) this learning tool is based on Van Hiele's theory, both the theory of the thinking levels and Van Hiele's theory of learning; (b) constructivist-oriented learning tool activities. This means that the geometric concepts learned are constructed by students through learning activities; (c) this learning tool specifically aims to improve students' thinking level from the analysis level to the informal deduction level on the material of quadrilateral concepts in junior high school. The concepts of quadrilaterals that are the focus of the study are the properties of quadrilaterals, the relationship between the properties of the types of quadrilaterals, and the definition of each type of quadrilateral; (d) this learning tool is used for remedial purposes, both individually and in small groups.

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