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Improving the Levels of Geometric Thinking of Secondary School Students Using Geometry Learning Video based on Van Hiele Theory

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ABSTRACT

An educational video called Video Pembelajaran Geometri (Geometry Learning Video = VPG) is developed in this study. The video is aimed to help year 9 students in improving their level of Van Hiele geometrical thinking. VPG is designed as an alternative aids to overcome the limitation of information and communication technology (ICT) usage in Parepare, South Celebes, Indonesia**.** Based on Van Hiele learning model, all topics in geometry for Indonesian Secondary School (Sekolah Menengah Pertama = SMP) are included in VPG in order to support the students who are going to continue their study further. The effectiveness of VPG was tested on 180 students categorized as 90 students from level 0 (L0), 60 students from level 1 (L1), and 30 students from level 2 (L2). Comparative Analyses on the results of adapted Van Hiele Geometry Test (VHGT) pre and post VPG usage indicated that there is a significant difference between the mean scores. It was also discovered that a significant improvement in geometric thinking level is occurred in the majority of the students.

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1. INTRODUCTION

The Van Hiele theory developed by Piere Marie van Hiele and Dina van Hiele-Geldof in the 1950s had been internationally recognized and affected the teaching of geometry in schools significantly. Russia and the United States are instances of countries that changed their geometry curriculum based on the van Hiele theory. Previous researches done showed that the application of van Hiele theory in geometry lesson brought about positive implications. The Van Hiele model is effective in motivating students and in creating a better environment for teaching and learning of geometry [1]. Van Hiele theory has been commonly used in many ICT-based geometry education applications such as geometry Sketchpad, geo explorer, Cinderella and 3D CABRI [2].

However, due to the limitation of infrastructure development and inappropriate curriculum, ICT-based applications are not fully accessible *in some places*. In the context of Parepare, a small city in the province of South Celebes, Indonesia, a preliminary study has been done on the usage of available technology-based educational infrastructure and teachers' ability in incorporating ICT in lessons prior to this current study. It was discovered that internet connection is only available to 9 out of 14 (60%) secondary schools. Moreover, it was also discovered that the ratio of computer to student was 1:50, and 10 out of 52 (23.8%) of the available math teachers have not acquired basic skills in using ICT in classroom teaching. Furthermore, 44% of the teachers stated that they have not used ICT in classroom teaching at all, and the information that geometry learning applications are available in the internet is known only by one single teacher among the 52.

Due to the limited technology-based educational infrastructure, the geometry lessons in Parepare are generally taught using the conventional method. Geometrical forms are drawn on the board or merely shown through the shapes of simple things. Consequently, the visual aspect, one of the most important aspects in geometry lesson, stated that visualisation is the very basis of geometry learning [3]. This is in line with van Hiele's theory which places the visual introduction of things as the first stage in its five-stage geometry thinking level.

Conventional geometry teaching contributed to the low potential in learning geometry among students in the junior high. This situation is evident in a preliminary study on the third-year junior high students in Parepare who, at the time, would be sitting for the National Examination soon. Among the 277 students who were sampled, it was found that the general score for basic geometry questions was 54 out of 100. Through analysis of the geometry questions, it was discovered that only 12.6% who managed to correctly answer questions on the introduction of geometry shapes.

Based on this issue, this study will produce an alternative learning tool by utilizing the available infrastructure (video+VCD) to help the third-year students to remember/understand the geometry lessons that had been learned since their first year. This tool will summarize all the topics on geometry taught in junior high in one learning module by incorporating the van Hiele-based teaching activities and utilizing multimedia in the making of the module into a learning video in order to maximize the visual process in learning.

1.1 Van Hiele Theory

Developed in 1957 by Piere Marie van Hiele and Dina van Hiele-Geldof, Van Hiele Theory had been published in 1973 by Freudenthal in his book "Mathematics as an Educational Task" [4]. Thereafter, a few research had been conducted that showed a connection between students' geometry ability and van Hiele's geometry thinking level. A positive relationship between the ability to write the geometry verification and students' geometry level [5]. Afterwards, Mason (1998) found that geometry thinking level can distinguish the high-ability students from the low-ability students in geometry learning. With respect to the significance of van Hiele's geometry thinking level, Atebe and Schafer (2008) stated that it is the framework in evaluating students' geometry thinking.

According to Van Hiele theory, there are five major steps to understand geometry topics [4], namely: Recognition (L0), Analysis (L1), Order (L2), Deduction (L3) and Rigor (L4). Each step is discussed in the next subsections.

(a) Level 0 (L0: Recognition).

This level is also known as the basic, the holistic and the visual level. At this level, students can only recognize geometrical shapes based on their visual characteristic. Apart from focusing on the geometrical shape of the objects, students are likely to see the object as a whole; hence they do not pay any effort to understand deeper characteristic of the objects

(b) **Level 1 (L1: Analysis)**

At this level, students involve their analytical thinking in order to understand the concepts of the given objects. For instance, students are able to study the objects by observing, measuring, experimenting, drawing and building the objects. Nevertheless, students at this level are not capable of explaining the relationships among different geometrical objects.

(c) Level 2 (L2: Order)

This level is also known as the level of abstract/rational, theoretical, correlational and informal deduction. At this level, students are able to correlate between different geometrical shapes, and to recognize general characteristic of particular objects and to explain it in hierarchical way.

(d) Level 3 (L3: Deduction)

This level is known as the formal deduction level. At this stage, students are able to make the connections between one geometrical object with another. Furthermore, they have already known how to sequence geometrical objects correctly.

(e) Levelt 4 (L4: Rigor)

At this level, students are able to debate by giving explanations and making comparisons on axiomatic geometry system. They are also able to understand deductive reasoning.

This study only focuses on the first three levels as suggested by previous researchers who stated that learning activities in primary school and secondary school began at L0 to L2 [6],[7],[8].

Students' geometry thinking level depends on neither their age or their maturity but rather on the lessons received. Hence, among the aspects needed to be focused on are the method and arrangement of the lessons in the classroom [9]. There are five phases of learning [4]:

(a) Phase 1: Information. At this stage, a two-way teacher-student interaction is essential in understanding certain geometrical shapes such as making observations, asking questions and understanding the vocabulary for that particular geometrical shape.

(b) Phase 2: Orientation. Students explore the topic about geometry as arranged by the teacher. The activities involved should enable students to identify the geometrical shape that is to be learned. Therefore, for students to master the level, they have to be assigned simpler tasks.

- **(c) Phase 3: Explanation.** Based on previous experiences, students are to express their opinions and discuss about the geometrical shapes that had been observed. At this stage, teachers act merely as facilitators.
- **(d) Phase 4: Free Orientation.** Students are able to solve more complicated problems such as open-ended problems. They gain experience by finding their own solutions or by completing tasks. Much of the relationships among objects are clarified through the interaction among students when making investigations.
- **(e) Phase 5: Integration.** Students survey and summarize what they have learned by making connections among the geometrical shapes. The teachers assist students in making a synthesis on each of the geometrical shapes. However, the form of synthesis done will not be affecting the geometrical concepts that had been learned at all.

The use of van Hiele's model in learning geometry can improve students' academic performance, motivate students, and create a much simpler environment in the teaching and learning of mathematics [1]. In addition, secondary school teachers have to be trained to understand the van Hiele thinking level to improve students' van Hiele geometrical thinking level [10]. In parallel to this, a few researchers have discovered the importance of van Hiele theory in explaining schoolchildren's learning of geometry [11],[12],[13],[14],[15].

1.2 Using Video in Learning

To apply the Video Compact Disk media in learning, teachers must first choose the appropriate materials for the program or learning requirements. This is followed by preparing the CD player and television set and after adequate introduction to the learning materials, the CD is played. The number replays depends on the needs and how fast the students are able to digest the learning materials. This method has been widely used in delivering lessons that utilizes numerous pictures, text, voices or animation. There are also several other reasons this method is widely used, such as: (1) the video can be played repeatedly, (2) the video show can be fast forwarded or slowed down, (3) there is no specific requirements for space, (4) its operation is relatively easy, (5) the VCD piece can be used repeatedly.

The importance of using video in learning as presented by Baggett (1984) [16] stated that by using video as a learning media, students are not only able to make a mental representation from the semantic understanding of a story in either audio or visual form but when presented together, each source gives an additional information and completion which helps students in remembering symbols or pictures naturally. In line with that, Cennamo (1993) [17] emphasized that a video presentation has to be designed for the purpose of improving students' mental *ability* and involving them in active learning. Among the previous researchers who discovered the importance of using video in learning, especially in mathematics, are [18] and [19].

1.3 Research Overview

There are over 100 different models of Instruction System Design (ISD), for instance the nine stages of teaching aid development process by Dick and Carey in 1996, the three stages of linear development by Seels and Glasgow in 1998, the eclectic model for evaluation program by Morison et al. In 2004, the 4C/ID model by Bollen in 2006, and the R2D2 model by Botturi et al. in 2007. However, most of the models are a form of the generic ADDIE model which is an acronym for Analyse, Design, Develop, Implement, and Evaluate [20]. Hence, the five stages in the ADDIE model is utilized in this study. The research design for this study is as summarized in Table 1.

Table 1. Research Design

Stage		Elaboration of Research Procedures
Stage 1 (Preliminary study + Analysis of important information)	a.	Data collection on the infrastructure of each junior high school (SMP) in the district of Parepare, especially the ones used in the process of teaching and learning mathematics.
	b.	Analysis of KTSP Mathematics Syllabus (Silabus KTSP Matematik) for junior high school (SMP) and high school (SMA) students.
	c.	Investigation of the more complicated topics on geometry in teaching and learning through interviews with senior math teachers and a few students.
	d.	Data collection and analysis of the geometry thinking level for students graduating from SMP in the district of Parepare using the van Hiele geometry level test (pre-test).
Stage 2 (Designing VPG)	a.	Introduction and understanding of the van Hiele geometry thinking level.
	b.	Identification and classification of lesson topics for practice.
	c.	Designing module in appropriate order based on the content and learning objectives.
	d.	Summary of learning activities in the learning module based on van Hiele geometry thinking level (Module 1, module 2, and module 3)
	e.	Designing of learning practice based on learning phase and van Hiele's geometry thinking level.
Stage 3 (Development of VPG)	a.	Development of learning module according to students' thinking level (Module 1, module 2, and module 3)
	b.	Development of learning module and activities with computer which is then video-recorded into a CD or DVD.
	c.	The video record is known as Video Pembelajaran Geometri (*Geometry Learning Video=VPG*)
Stage 4 (Execution of VPG)	a.	Classification of students according to their geometry thinking level.
	b.	Random selection of 90 students from Level 0 group, 60 students from Level 1 group, and 30 students from Level 2 group.
	c.	Execution of VPG in classrooms of 30 students each with level-appropriate module. Each module will be applied in three meetings (90 minutes per meeting).
Stage 5 (Evaluation of VPG)	a.	Execution of van Hiele geometry test (post-test) on all students in each group.
	b.	Analysis of pre-test and post-test results for evaluation on the extent to which VPG is able to help students in improving their van Hiele geometry thinking level.

2. RESEARCH METHOD

Selection of the study's subject began with the introduction of potential subject of study. First of all, each SMP graduate in Parepare's van Hiele geometry thinking level had been identified by measurement and categorization (in Stage 1) using van Hiele Geometry Test (vHGT). The vHGT used is the standard vHGT by staff from Cognitive Development and Achievement in Secondary School Geometry (CDASSG) [4].

Based on the vHGT results, a sub-group of students who are representatives of the three basic category in van Hiele geometry thinking level (Level 0 (L0), Level 1 (L1), and Level 2 (L2)) were selected for this study. The randomly selected subjects from each group were students who had studied geometry for three years prior to the vGHT. Selected groups will go through the teaching and learning process using VPG in the classroom. The teaching and learning session will be conducted in three meetings (90 minutes per meeting) that will be held during the students' break after taking the national examination. During the learning session, subject will be shown a video and do things (interactive) with guidance from the video. After the next learning session, they will be measured again using vHGT (post-test).

The answers to the questions in the vHGT pre- and post-test will be evaluated using a method developed by Usiskin, known as the "3 correct of 5" method. This means that if a respondent answers at least 3 out of 5 items correctly in any of the vHGT subtests, the student is considered to have mastered the level. The total weighted marks by Usiskin (1982) [4] are as follows:

1 mark for group criteria on items 1-5 (Level 1)
2 marks for group criteria on items 6-10 (Level 2)
4 marks for group criteria on items 11-15 (Level 3)
8 marks for group criteria on items 16-20 (Level 4)
16 marks for group criteria on items 21-25 (Level 5)

The scores obtained by the students are calculated based on the marks that had been determined by Usiskin in the 32 possible answers in determining the students' geometry thinking level table. The effectiveness of VPG is further investigated by dividing the students' improvement in geometry thinking level into four categories as shown in Table 2.

Table 2. Categories of Improvement in Geometry Thinking Level

Category	Explanation
Improvement between levels	Improvement of van Hiele geometry thinking level occurs in sequence (for example, from L0 to L1 or from L1 to L2)
The Skipping Phenomenon	Improvement of van Hiele geometry thinking level does not occur in sequence (for example, from L0 to L2 or from L1 to L3)
Improvement within a Level	There is no improvement of van Hiele geometry thinking level but an increase in the geometry thinking level score is obtained
No improvement	There neither improvement in van Hiele geometry thinking level nor in the geometry thinking level score

3. RESULTS AND ANALYSIS

Data analysis of the geometry thinking level (PBG) score from the pre- and post- test obtained is as shown in Table 3.

Table 3. Descriptive Statistic of Students' Geometry Thinking Level Score Before and After Learning with VPG

Cohort of Students According to Geometry Thinking Level	Before Implementation of VPG				After Implementation of VPG			
	N	Mean Score of PBG	Minimum PBG Score	Maximum PBG Score	N	Mean Score of PBG	Minimum PBG Score	Maximum PBG Score
L0	90	2.71	0	20	30	3.00	0	19
L1	60	2.20	1	17	70	10.03	1	27
L2	30	4,87	3	19	62	11.73	3	27
L3	0	-	-	-	18	-	-	-
Overall	180				180			

The results in Table 2 show that VPG can significantly improve the students' PBG. This can be observed from the increase in the mean PBG score for every group after the implementation of VPG. The mean PBG score for L0 group increased from 2.71 to 3.00 after learning with VPG. Similarly, the mean PBG score for L1 group increased from 2.20 to 10.03 whereas for L2 group, the score increased from 4.87 to 11.73 after the implementation. Another benefit observed is the increased number of students in the higher PBG, i.e. the number of students in L0 decreased from 90 to 30 students whereas the number of students in L1 increased to 70 and students in L2 increased to 62 after implementation. It appeared that after the implementation, 18 students were promoted to L3 in which at first there were none.

Table 4 shows the number and percentage of students, according to the 4 categories, whose van Hiele geometry thinking level improved after implementation of the VPG:

Table 4. Number and Percentage of PBG Increase after Implementation of VPG in Learning According to the Categories

Cohort of Students According to PBG (Before Implementation of VPG)	Increase in PBG (After Implementation of VPG)							
	Between Levels		Within Level		The Skipping Phenomenon		No Improvement	
	N	%	N	%	N	%	N	%
L0 (N = 90)	53	58.9	8	8.9	7	7.8	22	22.4
L1 (N= 60)	41	68.3	4	6.7	2	3.3	13	21.7
L2 (N = 30)	16	53.3	5	16.7	0	0	9	30
Overall (N= 180)	110	61.1	17	9.4	9	5	44	24.4

Table 4 shows that 75% out of 180 student respondents who had utilized VPG in learning showed PBG improvement, either between levels, within a level, or underwent the skipping phenomenon. Nevertheless, there are 24.4% students still who did not show any kinds of PBG improvement after learning.

The development of van Hiele geometry thinking level is further investigated by plotting a graph to observe the improvement of van Hiele geometry thinking level in each student from every level.

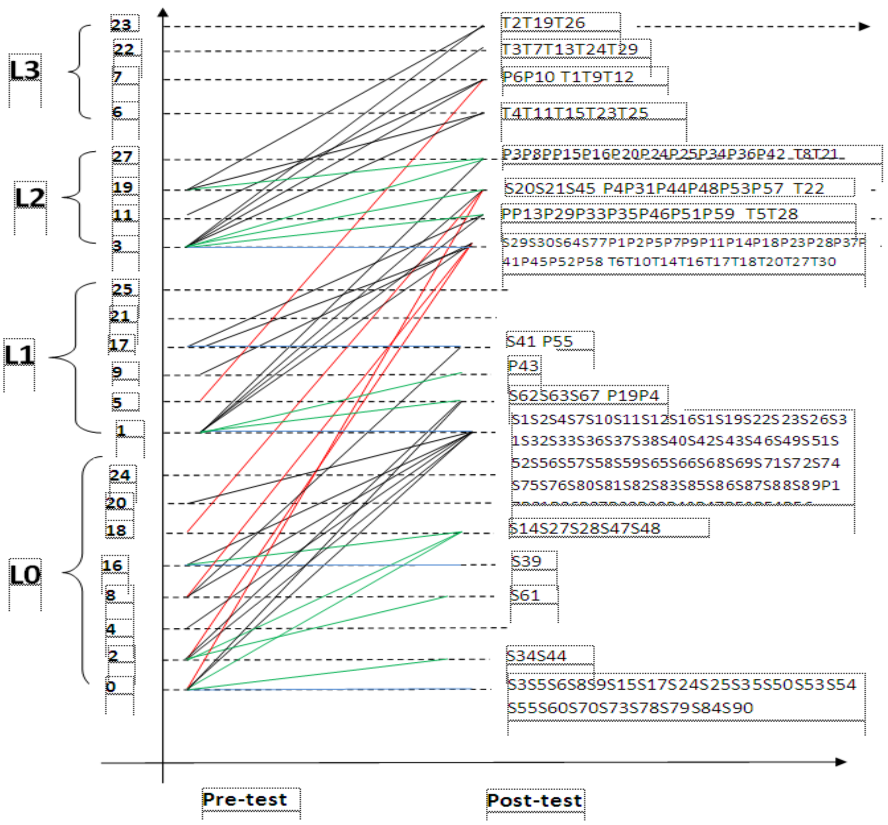

Figure 1. Development of Students' PBG Before and After Total Utility of VPG

From the results shown, it is clear that majority of the students showed improvement in their geometry thinking level following lessons in the classroom where VPG is implemented. It shows that this tool is helpful in improving the van Hiele geometry thinking level among the SMP graduates.

4. CONCLUSION

The study showed the effectiveness of VPG in improving the van Hiele geometry thinking level of SMP ninth grade students in Parepare. The results of the data analysis shows that out of 90 students in the L0 group sample, 60 of them showed improvement. In L1 group which consisted of 60 students, there were 43 who showed improvement, whereas in L2 group which consisted of 30 students, 15 of them showed improvement. The types of improvement shown were improvement between levels and the skipping phenomenon.

Apart from that, the data analysis also shows that there are still a number of students who did not show any improvement in the thinking level after utilizing the VPG. Some of the explanations for this occurrence are listed below:

a. Some students still find it difficult to analyze the connection between the geometrical shapes
b. There are students who have not understood the concept transition from two-dimensional geometry to three-dimensional geometry.
c. There are students who are not able to interpret the figures in geometry lesson.
d. There are students who still face difficulties in making their own definition of the geometrical shapes.

Based on the findings, there are a few suggestions and recommendations for future research, i.e.

a. VPG is recommended for districts with similar situation and environment as Parepare in the hope of improving the PBG of SMP ninth grade students.
b. Further development of VPG, especially the module 2 so that upon completion of the module, students are able to read charts and analyze the properties of the geometrical shapes.
c. Further development of VPG, especially the module 3 so that upon completion of the module, students are used to the concept application and classification of the basic geometrical shapes.

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