ANALYZING ELEMENTARY SCHOOL STUDENTS GEOMETRY COMPREHENSION BASED ON VAN HIELE'S THEORY

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ANALYZING ELEMENTARY SCHOOL STUDENTS GEOMETRY COMPREHENSION BASED ON VAN HIELE'S THEORY

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Abstract

The topic of geometry in elementary school is delivered to build and develop students' logical thinking skills. Students' comprehension of geometry topics is expected to develop the students' skills to solve every day problems. However, this learning objective has not been met as expected. In Indonesia, there are many elementary school students who still do not understand the basic concepts of geometry, such as shapes and planes. Based on this problem, the researcher conducted a study to examine students' comprehension of geometric concepts. This study is an experimental study, involving two classes; the first serves as experiment class and the second serves as control class. To solve the problem of geometric topics learning, the researcher utilizes the Van Hiele's theory. Geometry learning in the first class is delivered using a learning approach based on Van-Hiele's theory (experiment group), while the learning in the second class is delivered with conventional approach (control group). This study comprised of 150 students, drawn from primary five, representing two classifications of the medium and low performances from the selected schools found in Banjarmasin. Before conducting the study, the researcher designed learning scenario and research procedure to ensure the study goes as expected. The conclusion of this study is that students' comprehension of geometric concepts after Van-Hiele's Theory-Based Geometry Learning belongs to the medium category which is better than the students' comprehension of geometric concepts after conventional learning, which is in the low category. Conclusively, Van Hiele's geometry learning theory is found to be effective on the teaching and learning of mathematics.

Keywords: Concept comprehension, elementary school, learning geometry, mathematics communication, Van hiele learning theory

摘要

小学几何学的主题是为了培养和发展学生的逻辑思维能力。学生对几何主题的理解有望发展学生解决日常问题的技能。但是，这一学习目标尚未达到预期目标。在印度尼西亚，仍有许多小学生仍然不了解几何的基本概念，例如形状和平面。基于这个问题，研究人员进行了一项研究，以检查学生对几何概念的理解。这项研究是一项实验研究，涉及两个类别:第一个作为实验班，第二个作为对照班。为了解决几何主题学习的问题，研究人员利用 Van Hiele 的理论。第一堂课的几何学习是使用基于范·海勒理论的学习方法（实验组）进行的，而第二堂课的学习是通过常规方法（对照组）进行的。这项研究由来自小学五年级的 150 名学生组成，代表了 Banjarmasin 选定学校的中低表现的两种分类。在进行研究之前，研究人员设计了学习方案和研究程序，以确保研究符合预期。这项研究的结论是，范·海勒（Van-Hiele）的"基于理论的几何学习"之后的学生对几何概念的理解属于中等类别，比常规学习后的低层次的学生对几何概念的理解更好。结论是，范·海勒（Van Hiele）的几何学习理论对数学的教与学有效。

关键词: 概念理解，小学，学习几何，数学交流，范·海尔学习理论

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I. INTRODUCTION

Geometry is a fundamental component in elementary mathematics school curriculum. Its teaching and learning can help to develop and improve students' logical thinking skills [1][2][3][4][5]. This is in line with Kennedy [6] who states that "learning experience attained through geometry learning leads to the development of problem solving skills, reasoning skills and comprehension of other mathematical concepts." Many mathematical concepts can be explained through geometric representation. In addition, there are many geometric shapes that can be found in daily life, such as the shapes of houses, doors, blackboards, tiles, et cetera; so that these geometric shapes are familiar for primary school students. This short outline is enough to explain why geometry is important to be appropriately studied by primary school students.

Vojkuvkova [7] presents views on geometric thinking in schools, in regard to the theory of geometry learning. There are two points obtained from Van Hiele theory, they are: level of thinking and learning stages [8]. There are five hierarchical stages of students learning of geometric concepts, they, which have been developed or designed based on age [9]. These levels have varying indicators. From the Van Hiele, learning concept, there are also five sequential phases that are useful to learning geometry, they are: required data, guided orientation, interpreting meaning, open ended orientation, merging and integration [10]. Burger and Shaughnessy [11] explain in details characteristics of the five levels of van Hiele's geometric thinking concepts.

Based on these characteristics, to avoid difficulties in students' geometric learning, teachers and authors (in teaching or writing textbooks on van Hiele-based geometry learning) should employ communication technique and language that are compatible with students' level of thinking.

Several studies on geometry [12][13][14] report that many primary school students still have difficulties and make errors in comprehending geometric concepts. Among the errors are: students think that a shape with four sides is a square, and that only equilateral triangle is a triangle [12][15][16][17] many primary school students fail to comprehend the basic concepts of geometry [14] and most fifth grade students erroneously think that a rectangle is a square and that a triangle is right-angled triangle [18]. Other studies that employ geometry learning based on van Hiele theory find that fifth grade students have difficulties in understanding the characteristics of rectangle [13]; finds that learning using Van Hiele's levels can solve students' difficulties in understanding geometric shapes [19] that primary school students still have difficulties in identifying rectangle [20][21][22][23][24][25][26]; that students' geometric comprehension positively correlates to achievement in geometric shapes [27] and that students' achievement and motivation in geometry improve using van Hiele theory [28].

Learning using Van Hiele's phases of understanding leads to change in students' perception. It is therefore concluded that Van Hiele's geometry thinking concepts can help to improve students achievement and motivation in learning mathematics.

II. METHODOLOGY

This study is an experimental study, using the design of pre-test post-test control group with Van Hiele Based Geometry Learning approach. The study uses two different classes, the experiment group and the control group. In the former, Van Hiele-Based Geometry Learning is implemented, while in the latter, conventional geometry learning is delivered.

This study comprised of 150 students, drawn from primary five, representing two classifications of the medium and low performances from the selected schools found in Banjarmasin. The sampling process was conducted by considering the Banjarmasin City's Education Department's categorization of schools: the high level, medium level, and low level of schools.

The learning scenario used in this study is a series of written learning materials that serves to guide the researcher in implementing Van Hiele-Based Geometry Learning. The research instruments used in this study is Van Hiele Geometry Test, i.e. pre-test and post-test of concept comprehension skills developed by the researcher.

This study begins with preparing everything needed to support the implementation of the study. This preparation includes literary study on

geometry concepts comprehension and Van Hiele-based geometry learning, and designing the implementation of Van Hiele-based geometry learning. When the instruments are ready, the next step is sampling, followed by administering pre-test. The final step is administering the post-test.

The tool used in processing the data is the software of Microsoft Office Excel 2007 and SPSS V.16. The data analysis was conducted using t-test, Two-Way ANOVA, and Scheffe test, after normality and homogeneity tests. The development and validation of instruments' characteristics follow [1]. The following is an illustration of the test item used:

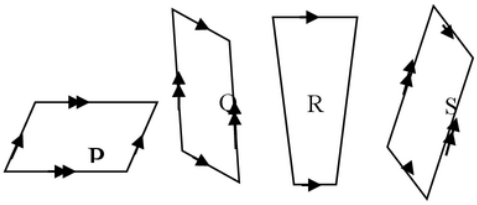


Fig 1. Examples of geometry concept comprehension test item

Data was analyzed using two-way ANOVA test (mean difference and existence of interaction between variables), Scheffe test (mean difference test), and chi-square test (association test)

III. FINDINGS

A. Analysis of Students Comprehension of Geometry Concepts

The data analysis in this stage consists of variance test of the experiment class (class that learns through Van Hiele-Based Geometry Learning/VH) and the control class (class that learns through Conventional Geometry Learning/Kv), normality test, and homogeneity test.

To measure the variance of experiment and control classes, an analysis of students' scores of preliminary test of conceptual comprehension and Mathematics communication skills is conducted, based on geometry learning approach and school level. Normality test is conducted using Kolmogorov-Smirnov Test (KS), while the homogeneity test is conducted using F-Test. The significance of mean deviance is tested using t-Test.

The preliminary test finds that students' conceptual comprehension and Mathematics communication skills before the treatment are in the Low category for the high, medium, and low levels of primary school. The following table displays the description of students' preliminary conceptual comprehension based on school level and student group which received treatment.

Table 1 Preliminary Geometry Concepts Comprehension Based on Learning Approach and School Level

. Based on Table 1, the following findings were made:

Overall, and in each school level, the results of pre-test on students' conceptual comprehension in class using van Hiele-based geometry learning (VH class) and in class that employs conventional learning (Cv class) are relatively low and are not significantly different. However, after treatment, the overall achievement of VH students is on sufficient category (32.59 of 48) and better than students' conceptual comprehension in Cv class (22.67 of 48). Therefore, from normalized gain, VH class students achieve higher gain (0.51) than Cv students' gain (0.20).

At each school level, in both classes (VH and Cv), students at VH class of low level and medium level schools achieved and gained higher conceptual comprehension skill than students at Cv class of high level school. This finding indicates that Van Hiele-based geometry learning plays greater role than conventional learning and school level in achieving conceptual comprehension skill.

The results of both tests on learners' conceptual comprehension in VH and Cv classes are presented in Diagram 1.

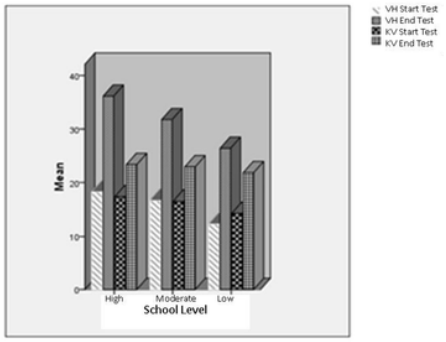


Diagram 1. Conceptual Comprehension based on School Level and Learning Approach

From geometry thinking level, some students in VH class achieve the thinking level of high visualization, some students achieve the level of low analysis, and some other achieve low level of informal deduction. Meanwhile, students at Cv class only achieve low visualization level.

Therefore, Van Hiele-based geometry learning is better than conventional learning in improving the level of students' geometry thinking.

Based on data from Table 1, the following findings are revealed: in general and on each school level, students' results regarding the test showed that both VH and Cv classes are in the category of low and are not significantly different. However, after the treatment, the students in VH class in general achieve good mathematical communication skill (27.07 of 32); which is better than mathematical communication skill of students in Cv class (14.52 of 32). From normalized gain, VH students have greater gain (0.78) than students in CV class (0.26).

At each school level, in both classes (VH and Cv), mathematical communication skills appeared to be higher. However, students at VH class of low level and medium level schools achieved and gained higher mathematical communication skill than students at Cv class of high level school. This finding indicates that Van Hiele-based geometry learning plays greater role than conventional learning and school level in achieving skill and attaining mathematical communication gain.

The result from both tests showed improved mathematical communication skills in the experimental and low in the control (conventional) class as presented in table 2:

Table 2. Mathematical Communication based on Learning Approach and School Level

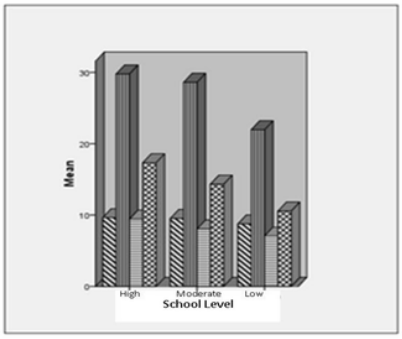


Diagram 2. Students' Mathematical Communication based on School Level and Learning Approach

Table 3. Normality Test of Students' Preliminary Comprehension and Mathematics Communication Skills Based on Learning Approach

Based on the data in Table 3, each learning approach yields $p > 0.05$; which means that the null hypothesis is accepted. In other words, the samples are from a population with normal distribution. To measure the significance of mean difference of students' preliminary skills in both group (experiment and control classes), t-Test is used.

H_o: There is no difference of students' preliminary skills.

H_A: There is difference of preliminary conceptual comprehension and

Mathematics communication skills of students in experiment and control classes. Testing criteria: If $p > 0.05$, H_o is accepted. The result of mean difference test is displayed in Table 3.

B. Analysis of Final Geometry Concepts Comprehension Skill

The analysis of students' final comprehension of geometry concepts (post-treatment) begins with examining students' final comprehension of geometry concepts based on the learning approaches and the school levels.

To find out whether the learning approaches and school levels provide significant effect on students' comprehension, the Two-Way ANOVA test is used. The result of this test is presented in Table 4.

Table 4. Summary of Two-Way ANOVA test on Students' Final Geometry Concepts Comprehension Based on School Levels and Learning Approaches

C. Learning Approach

To analyze the data in Table 4, the following criteria are used.

H_o: $\mu_e = \mu_k$ (there is no difference between students' final geometry concepts comprehension in experimental group and control group).

H_a : $\mu_e > \mu_k$ (the final geometry concepts comprehension of students who receive Van Hiele-Based Geometry Learning is better than that of students who receive Conventional Geometry Learning).

Table 4 shows that $F_{calc} = 83.346$, higher than $F_{critical} = 3.054$, on the significance level $\alpha = 0.05$, with degree of freedom two times 154 ($_{0.95}F_{2.154} = 3.054$); therefore, H_0 is rejected.

It is concluded that the final geometry concepts comprehension of the students who receive Van Hiele-Based Geometry Learning is better than that of the students who receive conventional geometry learning.

Analysis of interaction between learning approach and school level on conceptual comprehension and mathematical communication skills is presented in Tables 4 and 5.

Table 5. **Summary of Two-Way ANOVA test on Conceptual Comprehension Skill with School Levels and Learning Approach**

The results of analysis in Tables 4 and 5 indicate that there is no interaction between learning and school level on conceptual comprehension and mathematical communication. The graphs of interaction are presented in Figure 2 and 3.

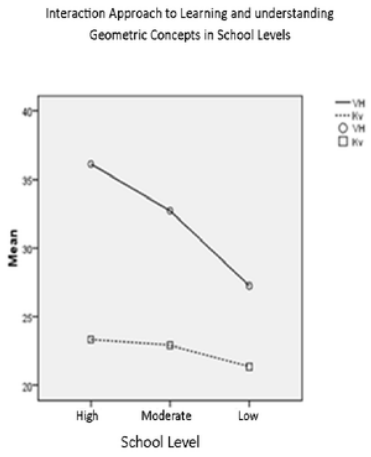
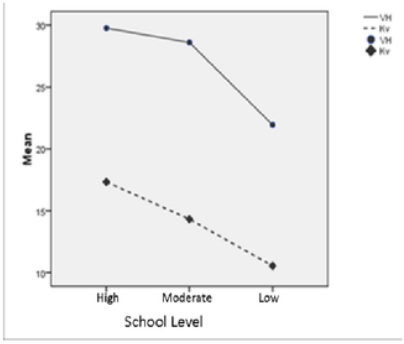


Diagram 3. Interaction of Geometry Learning Approach and school levels on the on Geometric Conceptual Comprehension



3.4. Association between Students' Conceptual Comprehension Skill and Mathematical Communication Skill

To find out about the existence of association between students' conceptual comprehension skill and mathematical communication skill, the contingency association is used.

Table 6. Scheffe Test of Mean Score of Students' Final Comprehension of Geometry Concepts Based on School Level

Based on the data in Table 8, p (0.004) is lower than 0.05 for the school levels of high and low, which means that H_0 is rejected. To summarize, there are two levels of schools (high and low) which are significantly different in terms of students' final comprehension of geometry concepts. Meanwhile, the school levels of high and medium and of medium and low are not significantly different in terms of students' final comprehension of geometry concepts.

IV. DISCUSSION

The result of data analysis established that students' comprehension of geometric concepts through Van Hiele-Based Geometry Learning (VH) is better than that of students who learn through conventional learning (Kv).

The geometric concepts comprehension achievements of students who received Geometry Learning (VH and Kv) are in the category of medium; in which the average achievement is in the range of 17-32 of the Ideal Maximum score of 48.

The average score of geometric concepts comprehension achievement of students who receive geometry learning of VH is above 65% (67.31%), while the average score of comprehension achievement of students who receive Kv geometry learning is below 65% (47.23%).

This finding is congruent with Van Hiele's Theory [7][8] that comprehension of geometric concepts is a skill developed through a process that builds from the previous schemes, previous understanding, and network of relationship among the concepts.

In Van Hiele-Based Geometry Learning, the students are motivated to be able to change the geometric concepts they already possess and understand, by comparing them with other concepts, so that they will have better comprehension of geometric concepts.

The finding of this study is also congruent with Piaget's theory that states that the most important part of comprehension is the evolutionary development of concepts; human continuously changes his ideas.

The first stage in the concept change is assimilation. In this stage, students use the

concepts they already possess to face new concepts. However, at one point, the students will face new problem that cannot be solved with their old knowledge. At this point, they need to radically change their concepts. This stage is called accommodation.

The impact of Van Hiele-Based Geometry Learning on students' geometry comprehension is not inherent with other factors. The findings of this study show that there is no interaction between the Geometry Learning approaches (VH and Kv) with the school levels (H, M, L) in improving students' comprehension of geometry concepts.

It means that, altogether, the factors of geometry learning approaches and school levels do not provide significant contribution towards students' geometry comprehension achievement. This also means that Van Hiele's theory is suitable for every student in every school level. In other words, the approach will not provide difficulties for students with low skills. Every asset of mental development and learning process are suitable for every student.

This study also shows that normalized gain for students' comprehension of geometry concepts in geometry learning based on Van Hiele's theory is generally in the category of medium, while that of students' in conventional learning is in the category of low. It means that students' achievement of geometry comprehension is better when they are taught with VH learning than when they learn in Kv learning.

Conclusion

Based on data analysis and discussion, several conclusions can be drawn. Students' comprehension of geometry concepts in Van Hiele-Based Geometry Learning (VH); both in general and based on school level, is in the medium category, better than that of students' in conventional learning (Kv), which is in the low category. The superiority of Van Hiele-Based Geometry Learning is also supported by the finding that students' comprehension of geometry concepts in low level of VH learning is better than that of students' in medium and high level of Kv learning.

Students' level of geometric thinking in Van Hiele-Based Geometry Learning (VH) is higher than that of students' in conventional learning. Generally, students' level of geometric thinking in Van Hiele-Based Geometry Learning is on the High Visualization level, for all levels of schools (H, M, L). Some students are on the Analysis and Informal Deductive levels. Meanwhile, students' level of geometric thinking in conventional learning is generally on the Medium Visualization level; and some students are in the Low Visualization level.

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