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To cite this article: P M Margaretha *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **243** 012056

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Students' geometric reasoning proficiency reviewed through Van Hiele's 5 levels of geometry

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Abstract. This study aims to find out the effectiveness students' geometric reasoning based on the van Hiele's 5 levels of geometry. In the analysis, researcher is applied as a method; the combination of qualitative and quantitative methods. The quantitative method is obtained by assigning geometric reasoning to the student, while the qualitative method is obtained from the interview result. The data analysis is performed by applying SPSS (Statistical Package for the Social Sciences) with t-test. The increase is illustrated by van Hiele's geometry post-test results which go up in comparison with the previous level. The geometry level of students mounts to a higher one. The levels discussed are van Hiele's 5 levels, which are level (0) (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). In the initial stage, the subject was tested through van Hiele's geometry test, and the indication of levels was checked as well. Next stage would be performing validated.. The results of the research show that the learning models through the class are more effective in increasing students' geometric level. Subsequently, it is expected that with the result of this analysis, teachers can upgrade students' geometric level, reviewed from other geometry theories.

1. Introduction

This research employs the result background of TIMSS (Trend in International Mathematics and Science Study) in Indonesia. The conclusion drawn from TIMSS results in 2015 is that mathematics needs reinforcement in integrating information, drawing conclusions, and generalizing the possessed knowledge to other aspects [1]. TIMSS is one of the international studies that gauge students' ability in Maths and Science. The purpose of TIMSS is to see the implementation of the curriculum planned by each country and to see the actual students' achievement in Maths and Science. The study is done periodically in every 4 years and coordinated with IEA (the International Association for the Evaluation of Educational Achievement)[2]. Indonesia commenced to take part in TIMSS study in 1999, and the most recent administration was in 2015. Indonesia was ranked the lowest 3rd in mathematic reasoning [1].

This has put forth an essential task for educators, especially for mathematicians. The study of geometry has become one of the pivotal things in life because geometry supports topics that require problem-solving skills [3]. Previous research has made it clear that the basic principles of mathematics that must be taught as a basis, consist of: understanding the problem and being able to solve it, being able to argue abstractly, constructing appropriate arguments and criticisms, making mathematical models, using appropriate props, using reasoning structures well [4]. From the research mentioned that reasoning should be taught even has become the basis in mathematical principles.

One of the most important figures in geometry is van Hiele. Van Hiele theory is a theory that categorizes one's level of geometry comprehension; they are level (0) (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor) [5]. In problem-solving context, on the other hand, research explains that the essential standard principles of mathematics that need be taught are: understanding problems and solving them, being able to argue in abstract demeanor, constructing critical and appropriate arguments, making a mathematics model, accurately making use of the props, using the structure of reasoning well [6].

Researchers think that learning in the present time is just the contextual one while there should be innovation that could upgrade the students' geometric reasoning to a higher level, which is RBL. RBL



is a method that makes use of contextual learning, authentic learning, problem solving, cooperative learning, hand on & mind on learning, and discovery approach [7]. RBL is implemented by the researchers to upgrade students' geometric level to a higher one based on van Hiele's 5 levels.

2. Methods

2.1. Participants

The place of this research on SMAN 1 Situbondo, Situbondo, Jawa Timur, Indonesia. Sample of research are 2 groups with random method, the groups with *cluster random sampling* [8]. Group use RBL method (Research Based Learning) as eksperiment group, and group with contextual teaching as control group.

2.2. Instrument

The research instrumen applied geometry test van Hiele, geometry reasoning test, planned learning based RBL method (Research Based Learning), planned learning based conventional teaching. Geometry test van Hiele are 2 kinds. There are pre-test and post-test. The result of this test is to know the effectiveness of RBL (Research Based Learning) method in geometric capability. Researchers used the geometry level in Van Hiele theory to find out the students' geometry abilities. Class control is class A using planned learning conventional geometry with teacher-centered learning. As in the experimental class, using planned learns geometry reasoning.

2.3. Research Design

The research method applied in this study is research-based learning. The implementation of the learning practice performed in this study can be illustrated as follows:

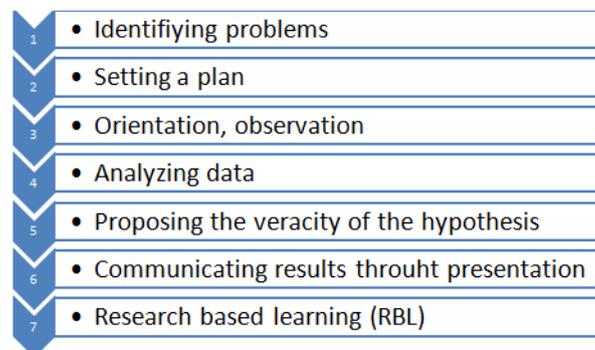


Figure 1. Illustrating the stages of research-based learning implementation

In this study, the subjects were asked to take a proficiency test of geometric reasoning through RBL, and the same assessor is present in other classes, but this time conventional method was employed. The indicators of geometric reasoning are constructed by the researchers through 7 indicators validated by geometry experts; the seven indicators are: proposing hypothesis; reviewing presentation related to the field, pattern, measurement and mapping; creating sequences of reasoning; having thoughts/ solutions apart from the context; making associations between different but related sciences; examining works through mathematical concept; and producing formula/ patterns in general from the previous steps.

Determined the problem is the first step. The problem in this research was the low ability of students' geometry at high school level. Geometry capability is assessed by using van Hiele geometry level. The second step is to plan. Planning on this research, students are given effective learning model that is RBL (Research Based Learning). RBL is used by applying the results of the researcher's evaluation on the preliminary study of the students' geometry ability test. Application of learning of student geometry used by van Hiele geometry. Such learning is different treatments. Students who are at the level 0 van Hiele geometry, only able to realize the existence of geometry properties, children still see the object geometry visually regardless of its properties; subjects who are at level 1 begin to

be able to see the properties of the geometry build but have not been able to make the relationship between wake-up geometry; subjects at level 2 have been able to see the relationship of geometry building properties [9]. Furthermore that is observation and analyzing data. And last is the application of RBL (Research Based Learning) to increase the geometry level of students to a higher geometry level.

This research employs triangulation, a mixed method comprising of quantitative and qualitative methods. The qualitative results are gathered through interviews and task of student, while the quantitative ones are collected through the administration of van Hiele’s geometry pre-test and post-test and geometric reasoning proficiency test. The variables observed are geometric reasoning learning as an independent variable and van Hiele’s geometry as a dependent variable. The samples used for experiment class and control class are randomly selected from a specific population with Pretest-Posttest only Control Design.

The following illustration (Figure 2) exhibits triangulation model, qualitative data triangulated with quantitative data to find out the effect of the treatment, which is the effect of geometry reasoning with RBL.

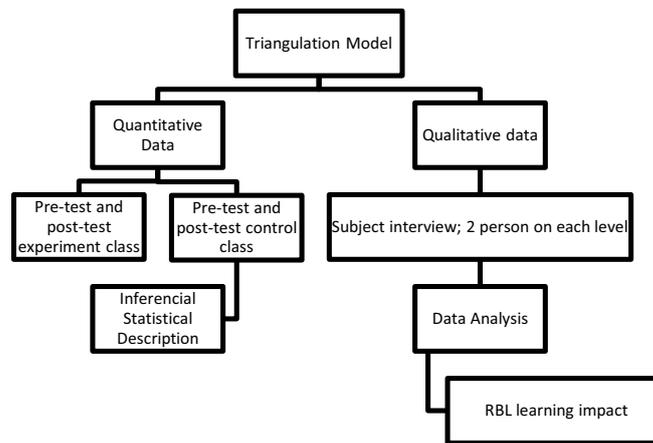


Figure 2. Triangulation Model (Hobri, 2018)

The class consists of control class that is class A with conventional method, and class B as experiment class with RBL (Research Based Learning) method. The design of this study is presented in table 1 below.

Table 1. Ekuivalent pre-test dan post-test

Grup	Pre-Test	Treatment	Post-Test
Control (A)	O ₁	Conventional metode	O ₂
Eksperiment (B)	O ₁	RBL (Research Based Learning).	O ₂

This research uses 2 randomly selected classes. Treatment (X) is given to the first class, but not to the second class. The group that receives treatment is referred to as experiment class and the one without the treatment is referred to as control class. In the research, the effect of the treatment is analyzed by using t-test statistics [10].

The instrument used is van Hiele’s geometry test sheet, geometric reasoning sheet, validation sheet, assessment guidelines sheet and interview sheet. All the instruments constructed by the researchers are validated by geometric mathematics experts. The instrument on geometry test sheet makes use of essays, based on the 7 indicators constructed by the researchers.

3. Results and Discussion

3.1. Results

All of the instruments the researchers have compiled are validated by geometric mathematicians. Validator consists of 3 experts. The Validator is then called V1, V2, and V3. Based on the validation of the geometry reasoning test sheet and the interview guide sheet, the mean total (V_a) value for all aspects is calculated based on the mean value for each aspect (I). Based on the calculation of validation analysis, $V_a = 4.75$ for geometry reasoning test, and $V_a = 4,33$ for interview guidance. Value V_a has more than 4, this indicates the instrument is valid category. In valid categories, interview guides, geometry reasoning tests need not be re-validated, but corrected in accordance with proposed revisions of validators.

The quantitative analysis is assisted by SPSS software version 17 with 2 classes, experiment class and control class. The qualitative data are collected with the aid of interview guidelines Data analysis are performed by using descriptive and inferential statistics. The collected information consists of frequency, mean, and deviation standard used to describe statistical data. Also, inferential hypothesis involves of RBL effect t-test between experiment class and control class [11]. A significant difference by 0,05 is obtained by independent sample.

Students in the control class that is class A, receive lessons with conventional methods. the students stay quiet and listen to the teacher's instructions. Students do the work of the teacher and get the value of the work done. Post-test results in this control class were also obtained on average lower than average experiment class results.

Students in the experimental class that is class B study in accordance with planned learning based RBL that has been prepared by researchers. Students are more active in asking questions, exchanging opinions, sitting in groups for discussion, brainstorming, and presenting learning outcomes. Class B is more active and compact in learning. Students in grade B are also more pleased to learn. Here is the average result of class A post-test as control class and class B as experiment class. The table descriptive statistics are below.

Table 2. Descriptive Statistics of Control Group and Eksperiment Group

	N	Mean	St. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
kontrol	36	53,9	13,1657	49,46	58,37
eksperiment	36	78,0	12,0876	73,96	82,14
Total	72	65,9	17,4698	61,88	70,09

Based table 1.2above, there is an average difference between the control class and the experiment class. The average score in the control class was 53,91 while the mean score in the experimental class was 78.05. Based on the table obtained with the SPSS program work is obtained minimum value in the control class is lower than the experimental class. That is, in the control grade the student's lowest score is 30 and the lowest grade in the experimental class is 56.

RBL learning method that was prepared by researcher using planed learning with geoemetric reasoning problem which compiled by researcher as many as 7 indicators. The following is a description of the achievement of 8 subjects as a sample of research consisting of 2 subjects with a level of 0 van Hiele geometry, 2 subjects leveled 1 van Hiele geometry, 2 subjects level 2 van Hiele geometry, and 2 subjects level 3 van Hiele. In this research there are no students who are at level 4 that is Rigor. At level 4 of this van Hiele geometry, students have been able to construct the given geometry. This level is obtained on the students. RBL can make the different result with sig 0,000 on table 1.3 below.

Table 3. Table T-Test for Equality of Means

Levene's Test for Equality of Variances		t-test for Equality of Means			
F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference
,527	,470	-8,103	70	,000	-24,13889
		-8,103	69,495	,000	-24,13889

3.2. Discussion

The results suggest that effective impacts of using t-test independent sample RBL are obtained through t-test analysis gathered from the score of pre-test and post-test of the two classes; normality test is performed immediately afterwards. The respondents consist of 72 students. The previous researcher mentioned that RPL can help motivate students and also improve the results of the study. It also helps students develop life aspects [12]. Students in level 0 (visual) see geometric objects visually without being aware of the objects' traits; students in level 1 start to see the traits of geometric objects, but they can't make associations between the objects; students in level 2 can see the relation between geometric objects; students in level 3 can prove a statement about geometry with logical explanations; students in level 4 can understand 2 elements, which are the differences between Euclid and non-Euclid geometry, and they are able to postulate about the formation of non-Euclid geometry[9]. The results of this research support the results of the previous research.

Reasoning geometry in RBL make integrated level geometry. Reasoning is a thought that integrates with begining of conclusions. The statement in accordance with the opinion states that "Reasoning is the process of drawing conclusion" [13]. Another argument suggests that reasoning is the use of logic to explain the solution of a problem or it can be said that reasoning is linking something known to something unknown [14]. There is also an opinion about reasoning that reasoning is a thought when one begins with information possessed, to the point that there is a conclusion [15]. The experimental design used was quasi experimental pretest-posttest equivalent control group design with 2 classes. The class consists of control class that is class A with conventional method, and class B as experiment class with RBL (Research Based Learning) method.

By applying RBL, students can step up one level. Students can develop and work effectively. By applying RBL, the classroom becomes a more active environment and the students step to a next geometric level, while in the class in which conventional model is applied, it was found that the students were more passive and stagnant, without any sign of improvement on the geometric level. Supported by the results of interviews on students of class A and class B is obtained as follows.

Class A / Control

Researcher : "How is the geometry study you have learned in the classroom?"
 Student1 : "Learning goes boring."
 Researcher : "Why boring?"
 Student1 : "Teachers' learning and teaching I feel saturated."
 Researcher : "then?"
 Student1 : "I also feel very sleepy and do not understand the material of the geometry."

Class B / Class Experiment

Researcher : "How is the geometry study you have learned in the classroom?"
 Student2 : "Learning is fun."
 Researcher : "Why is it fun?"
 Student2 : "My teacher's learning and teaching methods are different from ever before."
 Researcher : "then? What's different? "
 Student2 : "I discuss with my classmates, I exchange opinions."
 Student2 : "Then?"
 Researcher : "I am learning by being given contextual problems and self-employment."
 Student2 : "What do you want from learning other material maths?"

Researcher : "I want all the material even all the lessons in school using this kind of learning method."

Based the results and discussion conclude that student in experiment group can very happy and enjoy with their learning.

4. Conclusion

The results and discussion conclude that in comparison with conventional learning model Research Based Learning (RBL) model is more effective in efforts to increase students' geometric level to a level higher. Compared to other models, this RBL model can also increase students' geometric level based on van Hiele's 5 as well as students' geometric reasoning level.

Acknowledgement

I would like to extend my gratitude for the help and guidance in writing this article to Mathematics Department of Faculty of Teacher Training and Education, Jember University, Kalimantan 37 Jember 68121, Indonesia.

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