Volume 15 Number 1 (2023)
January-June 2023
Page: 713-722

E-ISSN: 2656-9779
P-ISSN: 1907-6355
DOI: 10.37680/qalamuna.v15i1.4260

QALAMUNA
JURNAL PENDIDIKAN, SOSIAL, DAN AGAMA

Experimentation of Transformative Learning and Realistic Mathematic Education Learning Models on Mathematics Learning Achievement

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Received: 20/03/2023 Revised: 28/05/2023 Accepted: 29/06/2023

Abstract

The research aims to investigate and evaluate the efficacy of different learning models on mathematics learning outcomes, specifically focusing on the students' van Hiele geometric reasoning capacity. The study employed a quasi-experimental design. The practice is carried out in Public Junior High Schools in Sukoharjo Regency, part of the Central Java Province in Indonesia. The utilized learning models were transformative learning, actual mathematics education, and direct instruction. The study encompassed a total of 281 individuals, who were selected from 9 classes across three distinct institutions. Data analysis is conducted with a two-way analysis of variance (ANOVA) approach. The research findings indicate that (1) the learning model has a positive and significant impact on mathematics learning outcomes; (2) the van Hiele level of geometric thinking ability has a positive and significant influence on mathematics learning outcomes; (3) there is a positive and significant interaction between learning models and van Hiele level of geometric thinking ability on mathematics learning outcomes; and (4) among the transformative learning, Real Mathematics Education, and Direct Instruction models, the transformative learning model yields the best mathematics learning outcomes.

Keywords Learning Models; Van Hiele's Geometric Thinking; Mathematics Education

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Published by Institut Agama Islam Sunan Giri (INSURI) Ponorogo; Indonesia
Accredited Sinta 2

1. INTRODUCTION

Learning outcomes are important and cannot be separated from the learning process. Learning outcomes are a measure of the success of a learning process. With learning outcomes, teachers can find out whether students have achieved the competencies that have been set. Learning outcomes are results achieved by someone after going through the learning process by first being given an evaluation after the learning process takes place. Learning outcomes can be in the form of changes in behavior that include the cognitive, affective, and psychomotor domains. Usually, learning outcomes are expressed in the form of numbers. High or low learning outcomes indicate the success of teachers in delivering subject matter in the learning process.

Several factors can influence learning outcomes themselves. Factors that can affect learning outcomes consist of internal and external factors (Cengiz & Eğmir, 2022). Internal factors that affect learning outcomes are factors that come from within students. The external factors are factors that come from outside the students themselves. Internal factors affecting learning outcomes include students' abilities and psychological and physical conditions. The external factors include instrumental factors, including the teacher's ability to deliver subject matter, learning methods, and learning facilities, as well as environmental factors around students (Susandi & Widyawati, 2022).

Referring to the explanation above, success in learning, especially mathematics, is strongly influenced by various factors, both internal and external. External factors affecting learning outcomes include family, school, and environmental factors (Cengiz & Eğmir, 2022). The internal factors affecting learning outcomes include physical, psychological, and fatigue (Cengiz & Eğmir, 2022).

Mathematics is one of the subjects taught in primary and secondary education. One of the goals of learning mathematics at the junior high school level is related to problem solving (Zuliyanti & Rizkianto, 2022). By paying attention to these objectives, the learning of mathematics is focused on the ability to solve problems (problem solving). In addition to problem solving skills, students need to develop creative thinking skills, namely the ability to see various possible solutions to a problem (Maulida, 2019). With their creative thinking, students can develop new ideas, innovations, and discoveries when solving problems.

Other factors that can affect learning outcomes are external factors, which include instrumental factors and environmental factors. Instrumental factors, in this case, include factors related to the learning process, namely how the teacher teaches. The research results conducted by Nur & Nurvitasari (2017) mention that geometry learning applied in schools is still conventional and does not differentiate students' thinking levels in geometry even though students' abilities are different. This hampers the progress of students' thinking levels, which are still low, and students' abilities in geometry material.

Learning geometry in schools requires an approach that involves students' internal factors, including cognitive style. Shoimin (2021) states that learning geometry is very important because (1) geometry makes humans understand the world and its contents, (2) geometry helps humans develop problem-solving abilities, (3) geometry helps humans understand other branches of mathematics because geometry plays a major role in mathematics (4) geometry helps humans in daily life (5) geometry helps humans in solving puzzles and having fun.

Most of what happened in schools in Sukoharjo Regency, the reality on the ground indicates that teachers only teach what is in the textbook in the mathematics learning process. Students only learn what will be tested. This condition does not support children's ability to solve their problems in the future. This impacts the emergence of the assumption in students that learning mathematics is a difficult subject.

The assumption that mathematics is a difficult subject impacts the emergence of students' negative attitudes towards these subjects. Negative attitudes towards mathematics subjects, in turn, will lead to negative perceptions of their ability to master the material well (Nugraheni & Marsigit, 2021). The same thing happened to students in junior high schools in Sukoharjo Regency. The reality at schools indicates that in mathematics, teachers only teach what is in the textbook, and students only learn what will be tested. This condition does not support students' critical thinking skills in solving their problems in the future.

The lack of development of the student's critical thinking skills is reflected in the low average score obtained by students in mathematics learning compared to the results of the Computer-Based National Examination in other subjects. The less-than-optimal ability of students to solve mathematical problems is reflected in the final test results for class VIII semester 1 in 2021/2022. Referring to the data collected from 41 public junior high schools in Sukoharjo Regency, it is known that the pure mean value of the test results obtained by students in learning mathematics is 55.90.

Based on preliminary research results, it is known that the number of class VIII students spread over 41 public junior high schools in Sukoharjo Regency is 8,030. They are grouped into 265 study groups so that the ratio between students and the number of study groups is 30:1. The average value of mathematics learning outcomes obtained from the final test of semester 1 in 2021/2022 is 55.90. The lowest average value is 24.60, and the highest average value is 86.21. Referring to the average completeness score of 70.0, out of the 41 schools, only five get an average score of > 70.00, or about 12.195% of the existing public junior high schools. These results indicate that most eighth-grade students of State Junior High Schools in Sukoharjo Regency have difficulty solving mathematical problems.

To overcome such conditions, a learning model is needed to form a new perspective or perspective on what is experienced and learned. This learning process aims to achieve transformative learning, namely a change in the student's frame of reference, which results from reflection on their learning experience (Purwati, 2020).

The success of a learning process is influenced by various components, including objectives, materials or materials, learning methods or models, media, teachers, and students. Regarding the learning model, based on the observations of researchers at several schools in Sukoharjo Regency, it was found that until now, there are still many lessons used by teachers in learning mathematics in schools using Direct Learning. Such a condition, in turn, tends to be in one direction, namely teacher-centered learning, so that it causes students difficulty in understanding the concept or material given (Nugraheni & Marsigit, 2021).

The Direct Learning method employed does not stimulate students to understand what is being learned because the Direct Learning process is one-way, namely teacher-centered, and students only wait for what the teacher gives, so students cannot independently take the initiative to solve problems related to the subject matter what students learn (Nugraheni & Marsigit, 2021). Students are less than optimal in learning because they may only memorize the materials they have just obtained. Students do not try to relate the new information obtained with the cognitive structure they already have.

The emergence of a sense of pessimism in students can impact the emergence of a sense of insecurity in students to master the material well. This is like what Mezirow (2008) said: "Their identity as a learner is linked to their interpretation of their experiences with math.". This opinion is interpreted that students will form a 'frame of reference' or mindset that they will not succeed in learning math material because they already have anxiety about facing math lessons.

The mindset problem is a very serious problem to be resolved immediately. The mindset problems faced in learning mathematics include: (1) mathematics is a very difficult subject, (2) students feel unable to master the material, and (3) the teaching method used by the teacher is considered inappropriate. The three problems are then concluded to be a pessimistic mindset. Based on these conditions, we need a learning model to change students' frame of reference to mathematics, especially geometry. This kind of learning model is often called a transformative learning model.

The transformative process includes 2 (two) stages, namely (1) the stage of disorientation or dilemma (disorienting dilemma) and (2) the stage of critical self-reflection. This model is considered suitable for overcoming the difficulties of children with learning difficulties in mathematics to students who unconsciously have formed a frame of reference that mathematics is a difficult subject.

The transformative learning model is seen as effective in improving students' cognitive abilities. This is because this learning model can empower students to build self-confidence. Mezirow (1997) mentions this ability as "empowerment to growth in mathematical knowledge and higher level thinking and problem-solving skills." Mezirow (1997) further explained that transformative learning is a learning model that requires "higher-order cognitive functioning involved in critical reflection, reasoning, and rational discourse." This model is considered appropriate for teaching mathematics, requiring students 'high-order thinking skills (Hasbi et al., 2019).

On the other hand, the realistic learning model, better known as the Realistic Mathematics Education (RME) learning model, aims to overcome problems in abstract mathematical concepts so that they become more real for students. This model emerged from Freudenthal's idea in 1971, which stated that mathematics is a part of human life, so students should be allowed to master mathematics by "managing and processing a real-world situation or a mathematical relationship" (Treffers, 1993).

Transformative Learning and Realistic Mathematics (RME) learning models are models in which students are more actively involved in learning. The teacher acts only as a facilitator of learning. With the use of learning models that encourage students to be more active in learning, maximum learning outcomes can be achieved at the end of the teaching and learning process.

On the other hand, students' understanding of mathematical material related to geometric concepts of flat-sided shapes is strongly supported by students' geometric thinking skills. The geometric thinking ability of students greatly affects the extent to which students understand the material that has been taught and proceed to a higher understanding (Ulandari et al., 2019). One theory that describes the development of learning mathematics, especially geometry, is van Hiele's theory of thought.

According to de Walle, van Hiele's theory was developed to help students' thinking processes in learning geometry (Van de Walle et al., 2014). Students learning geometry will go through 5 (five) van Hiele levels, consisting of level 1 (visualization), level 2 (analysis), level 3 (informal deduction), level 4 (deduction), and level 5 (rigor). Each level will describe the thinking ability of students in geometry. Based on the background of the problem above, the researchers are interested in conducting experimental research related to applying the Transformative Learning and Realistic Mathematics (RME) model and its effect on mathematics learning outcomes in terms of van Hiele's geometric thinking skills in students.

Based on the background described above, the objectives of this study can be stated as follows: (1) To determine and analyze the effect of learning models on students' mathematics learning outcomes; (2) To determine the effect of van Hiele's geometric thinking ability on students' mathematics learning outcomes; (3) To find out and analyze the interaction 1effect between the learning model and van Hiele's geometric thinking ability on students' mathematics learning outcomes; and (4) to find out which model provides better mathematics learning outcomes among transformative learning models, RME models, and Direct Learning models in each classification of van Hiele's geometric thinking ability.

According to Lachman & Pawlina (2006), Learning is a relatively permanent behavior change brought about by practice or experience. Mulyono (2017) says that learning is a process of an individual trying to achieve learning goals or outcomes, a form of relatively permanent behavior change. In the learning process in the classroom, according to Nurhadi and friends in Baharuddin and Wahyuni, students need to be accustomed to solving problems, finding something useful for themselves, and struggling with ideas(Baharuddin & Wahyuni, 2015).

Duval (2017) states that geometric thinking involves three activities, namely, the visualization process, the construction process, and the reasoning process. These processes can be carried out separately but are closely related. The three geometric thinking activities form an interaction.

The concept of geometric thinking, as described by Duval (2017), is as follows: (1) visualization is supported by reasoning, but (2) reasoning is not necessarily supported by visualization; (3) construction (using tools: ruler and compass, software) supported by reasoning; (4) visualization supported by construction; (5) reasoning can develop independently of visualization and construction. (5A) natural (inside or out) for naming, description, or argumentation (5B) propositions based on theory: definitions, theorems for deductive reasoning of problems. As for what is meant by the ability to think geometrically in this study, students can capture understanding and be able to express geometric material presented in an understandable form. The presentation consists of visualization, construction, description, and explanation that can provide an interpretation to classify it.

Van Hiele's geometric thinking ability is classified into 5 (five) levels. The five levels of geometric thinking ability, according to Van Hiele, can be explained as follows (Crowley, 1987):

Level 0 (Visualization). This initial level is called visual, which means recognizing and naming geometric shapes based on their visual characteristics and appearance. Students are not explicitly focused on the properties of the object being observed but view the object as a whole. By focusing on the shapes' appearance, students can review whether the shapes are similar or different. Therefore, students cannot understand and determine the geometric properties and characteristics of the shapes shown (Qomario et al., 2020).

Level 1 (Analysis). At this stage, the child can understand the properties of geometric shapes. At this stage, the child is familiar with the properties of geometric shapes, such as a rectangle having at least two lines of symmetry. If there is a question of whether all rectangles are parallelograms, then the child at this stage cannot answer the question because the child does not yet understand the relationship between shapes (Budiyanto et al., 2021).

Level 2 (Abstraction/Informal Deduction). At this level, students can see the relationship between the properties of a geometric shape and the properties of several geometric shapes. Students can make abstract definitions, find the properties of various shapes using informal deduction, and classify shapes hierarchically. However, students do not understand that logical deduction is a method for constructing geometry (Budiyanto et al., 2021).

Level 3 (Deduction). Students at this deduction level begin to understand the basic deductive systems of geometry. At level 3, students can use abstract statements about geometric properties and make conclusions based on logic, not instinct alone. Students have begun to be able to use axioms or postulates used in proof (Crowley, 1987).

Level 4 (Rigor). The last stage of children's cognitive development in understanding geometry is the stage of accuracy. The child begins considering the comparisons and differences between various basic geometric systems at this stage. For example, spherical geometry is based on lines drawn on a sphere rather than a regular plane or space (Chairil Hikayat et al., 2020).

2. METHODS

The research was conducted at a State Junior High School (SMP) in Sukoharjo Regency. The subjects in this study were class VIII SMP Negeri Sukoharjo Regency in the 2021/2022 academic year in 2nd semester. The study was carried out in the 2nd semester of the 2021/2022 academic year.

The type of research is experimental research. In experimental research, there are several forms of research design. This is explained by Campbell and Stanley, who say:

Regarding the research design model, the 12 models are divided into three major groups: pre-experimental, experimental, and quasi-experimental (quasi-experimental). (Darmadi, 2011: 181)

This research is a design using 3 x 3 Factorial Design.

The population of this study was all eighth-grade students of State Junior High Schools in Sukoharjo Regency in the 2021/2022 academic year. The number of public junior high schools in Sukoharjo Regency is 41, which are spread over 12 sub-districts. Class VIII SMP Negeri in Sukoharjo Regency in the academic year 2021/2022 is 8,030 students grouped into 265 classes. The samples used in this study were three state junior high schools. Each school takes 3 (three) classes, namely class VIII. Thus, the sample in this study consisted of 9 classes from 3 schools.

3. FINDINGS AND DISCUSSIONS

The subjects in the study were 281 class VIII students from 9 classes from 3 (three) different junior high schools. Subjects were given a test to measure van Hiele's geometric thinking ability. The average score of the test results is then grouped into 3 (three) categories, namely low with a score range between 0 – 1.33; moderate with a score range between 1.34 – 2.67; and high with a score range between 2.68–4.0. The data from the pre-test were then tested with the normal test to determine whether the population came from a normally distributed sample. The normal test results with the Liliefors test showed that each data group came from a normally distributed population. This is indicated by all test results with a significance of > 0.05, so H_0 is accepted, and it is concluded that the data comes from a normally distributed population.

Table 1. The Distribution of Students Based on van Hiele's Geometric Thinking Skills Classification

Learning Model	School	N	Student's Geometric van Hiele's Thinking Ability		
			High	Medium	Low
Transformative	SMP N 2 Kartasura	32	10	15	7
	SMP N Tawangsari	30	13	9	8
	SMP N 3 Sukoharjo	30	8	12	10
Sub Total		92	31	36	25
Real Mathematics Education	SMP N 2 Kartasura	34	11	11	12
	SMP N Tawangsari	32	10	11	11
	SMP N 3 Sukoharjo	32	9	8	15
Sub Total		98	30	30	38
Direct Learning	SMP N 2 Kartasura	31	8	11	12
	SMP N Tawangsari	30	6	10	14
	SMP N 3 Sukoharjo	30	7	8	15
Sub Total		91	21	29	41
Total		281	82	95	104

The next step is to provide treatment to all sample groups. All groups were treated with different learning models for three meetings, each 2 X 40 minutes. Before and at the end of the meeting, all subjects were given pre-test and post-test tests to measure learning outcomes before and after treatment. After the data is collected, the analysis prerequisite test is carried out on the post-test results using normal and homogeneity tests. The results of the post-test data normal test with the Liliefors test showed that each data group came from a normally distributed population. This is indicated by all test results that have a significance of > 0.05 so that H_0 is accepted, and it is concluded that the data comes from a normally distributed population. The results of the two-way analysis of variance with unequal cells are presented in the following table.

Table 2. The Summary of Two-Way ANOVA with Unequal Cells

Sumber	Sum Squares	Df	Mean Square	F_{obs}	F_{tab}	Conclusion
Learning Models(A)	2316.43	2	1158.2136	35.6551	3,00	H_{0A} rejected
Van Hiele Geometric Thinking Level (B)	7557.23	2	3778.6166	116.3230	3,00	H_{0B} rejected
Interaction Between Learning Models and van Hiele Geometric Thinking Level (AB)	352.18	4	88.0458	2.7105	2.37	H_{0AB} rejected
Errors	8835.60	272	32.4838	-	-	-
Total	19061.44	280	-	-	-	-

Based on the results of the two-way ANOVA test with unequal cells above, it can be explained as follows:

a. The results of two-way ANOVA analysis with unequal cells showed the $F_{stat\ A}$ of 35.6551 with $p < 0.05$. Therefore, H_{0A} was rejected, and it can be concluded that there are differences in the effect between rows on the dependent variable. This means that the three learning models affect mathematics learning outcomes differently.

b. The results of two-way ANOVA analysis with unequal cells showed the $F_{stat\ B}$ of 116.3230 with $p < 0.05$. Therefore, H_{0A} was rejected, and it can be concluded that there are differences in the effect between columns on the dependent variable. This means that the level of van Hiele's geometric thinking provides different effects on mathematics learning outcomes.

c. The results of two-way ANOVA analysis with unequal cells showed the $F_{stat\ AB}$ of 2.7105 with $p < 0.05$. Therefore, H_{0AB} was rejected, and it can be concluded that there is a significant interaction effect between the rows and columns on the dependent variable, namely the learning models and van Hiele's geometric thinking ability on mathematics learning outcomes.

Table 3. Mean and Marginal Mean

MODEL	Van Hiele's Thinking Ability			Marginal Mean
	High	Medium	Low	
Transformative Learning	77.16	69.67	61.12	69.87
RME	71.20	69.20	59.89	66.20
Direct Learning	67.43	62.90	56.39	61.01
Marginal Mean	72.49	67.45	58.81	

The results of the post-ANOVA test calculation between rows are presented in the following table:

Table 4. The Summary of Multiple Comparisons among Rows

Ho	FOBS	$2F_{0.05;\ 2;\ 296}$	Keputusan Uji
$\mu_1 = \mu_2$	19.629	6	H_0 rejected
$\mu_1 = \mu_3$	110.532	6	H_0 rejected
$\mu_2 = \mu_3$	39.18	6	H_0 rejected

Based on the summary of the results obtained from Table 6 above, it can be concluded as follows:

d. H_0 is rejected because F_{12} = 19,629 with $p < 0.05$. This means that applying the Transformative Learning and RME learning models provides different learning outcomes. Table 7 shows that the marginal mean for the Transformative Learning model has better mathematics learning outcomes than the RME learning model.

e. H_0 is rejected because F_{13} = 110.53 with $p < 0.05$. This means that the application of the Transformative Learning model and the Direct Learning model provides different learning outcomes. Table 6 shows that the marginal mean for the Transformative Learning model has better mathematics learning outcomes than the Direct Learning model.

f. H_0 is rejected because $F_{2\ 3.}$ = 39.48 with $p < 0.05$. This means that applying the RME and Direct Learning models provides different learning outcomes. Table 6 shows that the marginal mean for the RME learning model has better mathematics learning outcomes than the Direct Learning model.

The first hypothesis in this study states that students' mathematics learning outcomes in Transformative Learning are better than those in RME and Direct Learning. RME learning is better than direct learning for students' mathematics learning outcomes. Based on the analysis of variance in two ways with unequal cells, the value of F_A = 35.655 with $p < 0.05$. This means the H_{0A} is rejected. This shows different effects between the learning approaches used on student learning outcomes. In other words, the Transformative Learning, RME, and Direct Learning models affect mathematics learning outcomes differently. A multiple comparison test was conducted to find a better learning model.

The results of the multiple comparison test analysis of the comparison between the use of the Transformative Learning model and the RME model obtained F_{Stat} = 19. with $p < 0.05$, so Ho is rejected. The mean of the Transformative Learning model is 69.87, while the RME model is 66.20. This shows that the Transformative Learning model is better than students' mathematics learning outcomes in RME learning.

The multiple comparison test analysis of the comparison between the use of the model and Direct Learning obtained Fcount = 110.532 with $p < 0.05$. Therefore, H_0 is rejected. The mean of Transformative Learning is 69.87, while Direct Learning is 61.01. This means that the learning outcomes of students taught using the Transformative Learning model are better than students' learning outcomes in direct learning.

The multiple comparison test analysis results of the comparison between the RME and Direct Learning models obtained F_{Stat} = 39.18 with $p < 0.05$. Therefore, H_0 is rejected. The average RME model is 66.20, while Direct Learning is 61.01. This shows that learning the RME model produces better outcomes than students' mathematics learning outcomes in direct learning.

The hypothesis that the Transformative Learning model is better than the RME and Direct models and that the RME model is better than Direct Learning is true. This is possible because the Transformative Learning model is student-centered. The Transformative Learning model is a series of activity stages (phases) organized so that learners can master the competencies that must be achieved in learning by playing an active role.

This finding is supported by the results of research conducted by Hassi & Laursen (2015), Johnson & Olanoff (2020), and Bonghanoy, Sagpang, Alejan Jr, & Rellon (2019). The result of research conducted by Hokkanen, Bhatnagar, & Sillanpää (2016) showed that the Transformative Learning model could improve academic achievement, interest in learning, and students' self-confidence in learning science. The RME learning model can produce better mathematics learning outcomes than the direct method. This is possible considering the RME learning model presents an active student learning condition and involves students in problem solving through the stages of the scientific method. Through this RME, it is expected that students can learn knowledge related to the problems presented and can have a skill in solving problems.

This finding is supported by the results of research conducted by Jones, Laurens, Herba, Barker, & Viding (2009), Tong, Winkelmayer, & Craig (2014), and Wilmé et al. (2016). The findings of these studies indicate that the use of the RME learning model is effective in improving student learning outcomes compared to the conventional model. This is because, in RME, students are trained to solve problems.

In the low classification of van Hiele's thinking ability, students subjected to the Transformative

Learning model will produce better mathematics learning outcomes compared to the RME and the Direct Learning models. Students subjected to the RME learning model will produce better mathematics learning outcomes than the Direct Learning model; some are proven, and others are not.

4. CONCLUSION

Based on the analysis and discussion results, it was concluded that students subjected to the Transformative Learning model gave better mathematics learning outcomes than students subjected to the RME and Direct Learning models. Students subjected to the RME learning model give better outcomes than those subjected to the Direct Learning model. The results of this study can be used as input for educators to improve the quality of the teaching and learning process and learning outcomes, especially the material on the flat side. There is no best learning model, so it is unnecessary to use a certain model in the material. Teachers in delivering material and using learning models can affect student learning outcomes. One student with another student has different abilities in receiving material, so the use of learning models must be in accordance with the material being taught.

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