Generative Learning Models Assisted by Virtual Laboratories to Improve Students' Creativity in Physics

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Abstract: Difficulties in teaching abstract concepts can be overcame by using computer technology. Computer technology provides opportunities to understand abstract concepts, such as the use of virtual laboratories. The purpose of this study is to examine the effectiveness of generative models assisted by virtual laboratories to the students' physics creativity. The research and development used the 4-D model consists of 4 stages of development, namely Define, Design, Develop and Disseminate. The research was conducted using quasi-experiments method in one high school in Mataram. This study used pretest-post non-equivalent control group design consisting of experimental and control groups. The data were analyzed using the independent sample t-test. The increase in each aspect and indicator of creativity was measured using the *N*-gain test. From the analysis, it is found that the students' creativity in the experimental group is higher than in the control group. It indicates that the generative model assisted by virtual laboratories effectively improves the students' verbal, figural, numerical and procedural creativities in physics learning.

Keywords: creativity, virtual laboratories, generative models, physics learning

Introduction

Physics learning can train students to develop higher-order thinking skills. One part of higher order thinking skills is creative thinking skills. Creative thinking skills must be developed as an implementation of the curriculum applied in schools (Shaheen, 2010). Thinking is described in terms of chains of implicit symbolic transformational responses (Berlyne, 1965). Students who have good thinking skills will have good responses. Creativity is very dependent on the speed of students in responding to an idea. Students with better thinking skills, they will generate ideas and execute those ideas more effectively (better responses). The development of better thinking skills that will greatly affect the quality of creativity and better creativity is a high level achievement (Gunawan et al, 2018). To achieve these goals, experimental activities is recommended by the number of researches (Lian, Kristiawan, &Fitriya, 2018; Bloom & Dole, 2018).

The alternative to conduct a creative learning environment for physics is by implementing a generative learning model.Generative learning model is a model that can train students in conducting exploration activities to obtain new concepts through the initial knowledge they have with the stages of preparation, focusing, challenges and applications (Anderman, 2010). Teachers can improve students' abilities to remember and connect new ideas through generative strategy designs (Basaffar, 2017). According to generative learning theory, meaningful learning occurs when learners engage in appropriate cognitive processing during learning, including selecting (i.e., paying attention to relevant incoming information), organizing (i.e., mentally arranging the information into a coherent structure), and integrating (i.e., connecting the verbal and pictorial representations with each other and with relevant

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prior knowledge activated from long-term memory). Generative learning is the process of taking incoming information and transforming it into usable information by engaging in appropriate selecting, organizing, and integrating (Parong& Mayer, 2018). According to Anisa, Masrukan&Dwijanto (2017) generative learning models can foster students' creative thinking abilities. Practicing creative thinking will help students to understand the thinking processes of individuals and others by applying the cognitive process in problems solving (Lin &Wu, 2016; Lin et al, 2017). Also, it affects the improvement of the learning quality and motivation of the students (Cropley, 2012).

To achieve the goal, experimental activities is recommended by the number of researches. Higher order thinking skills could be improved through experimental activities (Prayitno et al, 2018). However, nowadays, most of the physics learning consists of abstract concepts that are difficult to prove and visualize by a real experimental activities (Tuysuz, 2010). Hence, the teacher must creatively use a learning source that will be able to convey the intended physics concepts (Hermansyah et al, 2019; Stanojevic, Cenic&Cenic, 2018).

Creative thinking abilities can be improved through the use of computer technology in learning. Computer-based learning can improve student creativity (Wyse &Ferrari, 2014). Computer-based learning can stimulate and enable children to discover various aspects of experience and train to develop their creativity (Stosic&Stosic, 2014). High creativity can affect learning outcomes because it makes it easier for students to solve a problem).Hermansyah et al. (2019), in his research concluded that the application of virtual labs in physics learning can enhance students' conceptual understanding. Good conceptual understanding results from a good creativity process. from here, we can understand that if the virtual lab is able to improve students' conceptual understanding then of course it can be used to help develop student creativity. this was also mentioned in a study by Gunawan et al., (2018) that the use of virtual lab can increase student creativity.

Computer-based learning can take form of many digital formats, such as animation media or virtual laboratory media (Adawiyah et al, 2019; Mashami&Gunawan, 2018; Gunawan et al, 2018). A virtual laboratory is a simulation of experimental activities to facilitate students in practicing virtually (Sugiarti, 2015). Equipment available in a virtual laboratory is a simulation program that contains systems, processes, or phenomena (Kolloffel&Jong, 2013).

The exploration provided in virtual simulation is designed to help the students in understanding concepts and minimize errors when practicing in a real laboratory (Tawil&Dahlan, 2017; Munawar et al, 2018). Virtual laboratories allow students to conduct experiments quickly and easily (Kolloffel& Jong, 2013). Park (2019) recommended to implement the virtual laboratory as a tool to elaborate an abstract scientific phenomenon in science teaching & learning. It emergence is not to replace the important of real laboratory to conduct a real experiment, but as an alternative if the intended research cannot be done in real laboratory due to the lack of learning sources (Gunawan et al, 2018).

This research is important to get empirical evidence related to finding differences in increased creativity through generative learning assisted by virtual laboratories. The creativity measured in this study is on verbal, figural, numerical and procedural aspects based on creativity indicators.Gunawan et al (2018) used the virtual laboratory to improve the students' creativity in verbal and figural aspects. However, besides of verbal and figural aspects, there are other aspects in creativity including numerical and procedural aspects. Reflect to the aforementioned reasons, the present study was aimed to examine the effectiveness of virtual laboratories in improving the students' creativity in all aspects of physics.

Materials And Methods

The type of this present study was a Research and Development (R & D). It used the 4-D model consists of 4 stages of development, namely define, design, develop and disseminate to develop a valid, practical and effective generative model-based learning assisted by virtual laboratories.

The study was conducted in one of the secondary schools in Mataram with Pretest-Posttest Non-Equivalent Control Group design. The experimental and control groups were selected by purposive sampling technique. Both groups were given pre- and post-test tests in the form of verbal, figural, numerical, and procedural creativity test instruments. Indicators of creativity include fluency, flexibility, originality, and collaboration. Learning activities use generative models assisted by virtual laboratories in the experimental group and conventional models in control group.

The data were analyzed using hypothesis test and normalized gain scores. Afterwards, we checked the homogeneity of the data using Levene test and the normality of the data using Kolmogorov-Smirnov. Since it was found that the data were normally distributed and have a homogeny variance, the research hypothesis was tested using independent sample t-test. Furthermore, the increase of the students' creativity was assessed by using the *N*-gain test.

The students' creativity is called high if *N*-gain> 70%, medium if *N*-gain30% ≤ 70% medium and low if *N*-gain <30% (Hake, 1999). All of the data analysis processes were doneby using statistical software, namely Version 21 of the Statistical Package for the Social Science (SPSS).

Results

After conducting a treatment, the post-test were carried out to examine the increase of students' creativity skills in physics. The result can be found in the following Figure 1.

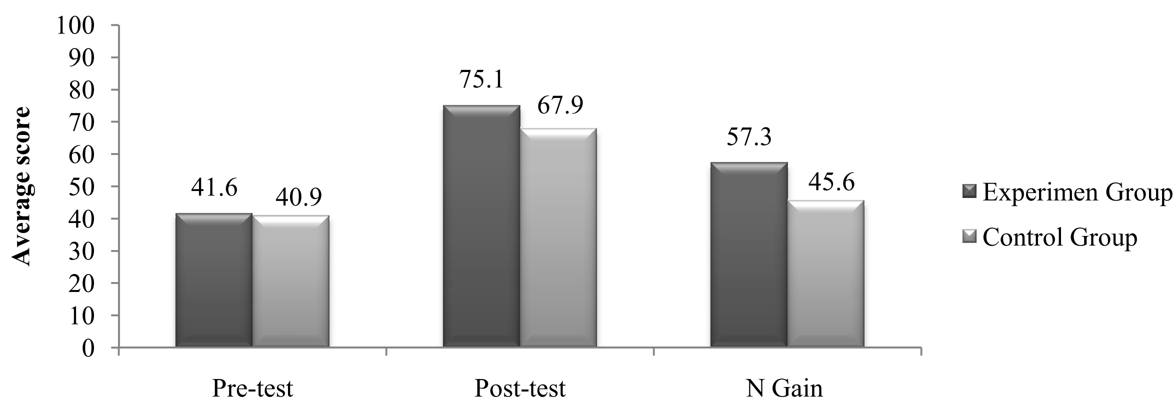

Figure 1. Comparison of the Average Score of Student Creativity

As can be seen in Figure 1, the experimental group obtained higher *N*-gain score (57.3%) than the control group (45.6%). According to its category, the students' creativity in both groups are in the medium category.

Before testing the research hypothesis, the normality and homogeneity test were conducted. The following Table 1 showed the homogeneity test with Levene test (significant level of 0.05) for the students' creativity in the post-test.

Table 1. Homogeneity Data for Group Final Tests Experiments and Controls

Category	Result
Results of Calculations	0.20
Significant level	0.05
Degree of Freedom	66
Variance	Homogenous

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The result of calculation in Table 1 marks the value of 0.20. According to Levene test the calculation results more than 0.05 means that the data have the same variance. Hence, we can concluded that the control and experimental groups were homogeny in variance.

Furthermore, a normality test was conducted to find out the normality of the data distribution. The following Table 2 is the result of Kolmogorov-Smirnov normality test.

Table 2. Normality Test Results in Both Groups

Group	Kolmogorov-Smirnov		
	Statistic	Degree of Freedom	Significant level
Experiment	0.12	36	0.20
Control	0.15	32	0.65

Table 2 shows that the results of the significant level in the experimental and control groups are larger than 0.05. Hence, it can be concluded that the final test data of the two groups were normally distributed.

Since the data have a homogeneity variance and normally distributed, the hypothesis of the study was tested using independent sample *t*-test to determine the differences in student creativity taught by generative models assisted by virtual laboratories and conventional learning models. The result can be found in the following Table 3.

Table 3. Independent Sample *t*-test in Both Groups

Group	*N*	Independent sample t-test		
		T	Degree of Freedom	p
Experimental and Control	68	5.98	66	0.008

From the Table 3, it can be seen that the p values < 0.05. It means the hypothesis test results used sample t-test independence test show that there are differences in student creativity taught by generative models assisted by virtual laboratories with students taught with conventional models.

Furthermore, the level of creativity of the students were analyzed according to the verbal, figural, numerical, and procedural aspects and to every indicator of creativity that have been described in Munandar (2012). The following Figure 2 showed the comparison between the students' creativity increase in both groups.

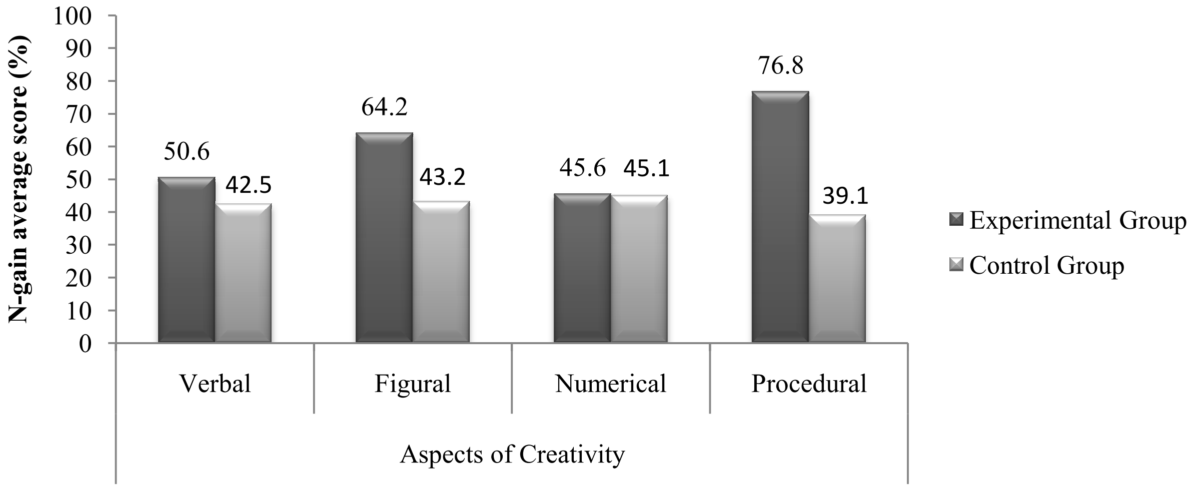

Figure 2. Comparison of the Increase in Every Aspect of Creativity Indicators

Figure 2 shows that the students in experimental group got the high category in procedural aspect while in other aspects they got medium category. The students in control group got all aspects in the same category which is medium.

In addition, the comparison in increase of each creativity indicators presented in Figure 3.

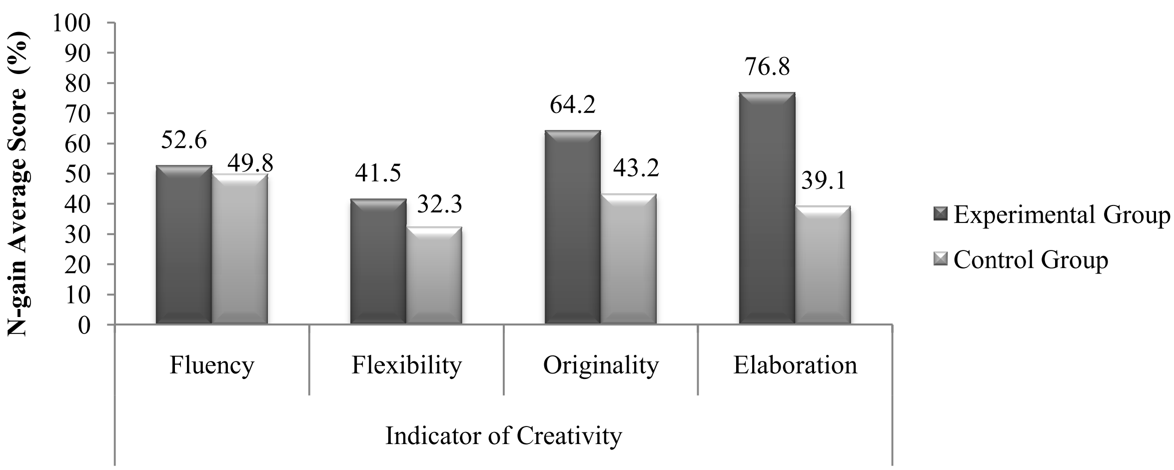

Figure 3. The Comparison of Increase on Creativity's Indicators

The result in the Figure 3 indicates that the increase of the students' creativity in the experimental group better than the control group. It can be seen that the average percentage of *N*-gain in the experimental group with a high category occurs in the elaboration indicator. Meanwhile fluency, flexibility, and originality indicators are in the medium category. On the other hand, all indicator creativity of the students in the control group is in the medium category. Also, all indicator of creativity in the control group were in smaller percentage compared to experimental group.

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Discussions

The result shows that the generative model with a virtual laboratory assistance can improve students' creativity in physics learning. The lesson in experimental class was implementing based on the following sequences.

In the preparation stage, the teacher provides simple problems in daily life related to the material concept to motivate the students in learning. Next, the students translate the initial problem to the physical statement and formulate the hypotheses to find the solution. In the next stage, the students elaborate the hypothesis by conducting an experiment in a virtual laboratory. The main focus of this stage is that the students are able to connect their prior knowledge with new information they found to enhance their creativity. On the last stage, that students apply the new concepts learned in a variety of different contexts.

The generative learning model assisted by virtual laboratory is able to improve the students' creative since it helps the students to conceptualize the abstract concepts in physics. The result is supported by the findings of Park (2019) that the students are easily explain scientific phenomena after being given simulation-based learning (Park, 2019). Gunawan et al (2017) also found that project-based learning models assisted by virtual media increase students' creativity in learning physics.

Based on Figure 2, the experimental group experienced a significant improvement in the overall aspects of creativity. These findings are in line with the results of the study of Dewi et al (2016) which showed that the results of the figural creativity test had improved to the high criteria since the students had a better ability to give ideas related to the images. It is possible due to the opportunities given for the students to think divergently to combine verbal and oral ideas, associate with shapes and images, observe the regularity of patterns in accordance with the learning activities. Gunawan et al (2017) also found that virtual media improves verbal and figural creativity in physics learning using generative model and virtual laboratories.

In addition, the results showed that the experimental group students obtained higher performance on all creativity indicators compared to the control group students (Figure 3). The highest increase occurred in the elaboration indicator. According to Gunawan et al (2018), the elaboration indicator shows the ability of the students to describe a problem in detail. The present findings found that the students were able to give detail to a problem through the knowledge gained from virtual experiments. After being able to create new ideas, the students can explain their findings in more detail during the group discussions.

The improvement in the indicators of flexibility means that students able to provide diverse ideas by looking at problems from different perspectives(Munandar, 2012) or different from other students (Gunawan et al, 2017). The generative learning model assisted by a virtual laboratory enable students to provide answers from different perspectives after understanding the basic concept.

The Improvements in the originality indicators are caused by the students' opportunities to illustrate images using original thoughts from observing the shapes of objects. An interesting finding from the results of the creativity test is that students gave explanations about the material that had been studied using their own language and thoughts based on experiments and the results of discussions. In line with the result, Sugiana et al (2016) stated that learning with generative models can help students to explore new knowledge. Then, it is stored in students' long-term memory.

Last, the improvement in fluency indicators is not too differ from the results obtained by the control group students. Gunawan et al (2018) stated that the fluency indicator is the students' ability to give as many new ideas as possible, even though it is not directly related to the process in finding the solution of the problem. Hence, fluency indicators will increase if students are able to give as many relevant answers as possible. Therefore, the fluency scores of the students in experiment and control groups were not significantly different.

Based on the results of the final test, it shows that the students have been able to master all aspects and indicators of creativity during the learning process with generative models assisted by virtual laboratories. Students are able to express a number and varied ideas, thinking styles, and delivery methods. The students are also able to describe the physical problem and phenomena correctly and in great detail.

The support of the finding can be seen in the number previous studies. According to Horng et al (2005), the learning experiences produce creative learning. Learning with a virtual laboratory alo has provided positive responses and increased student creativity (Gunawan, 2017). This statement is strengthened by Wyse & Ferrari (2014) that student creativity can be improved through computer-based learning.

Conclusions

The implementation of generative models assisted by virtual laboratories in physics learning is effective to improve the students' creativity. The increase of the creativity score in the experimental group is higher than the control group in each verbal, figural, numerical, and procedural aspects. The experimental group also overcome the control group in every indicator of creativity: fluency, flexibility, originality, and elaboration. Hence, it is recommended for the teacher to use generative models assisted by virtual laboratories to teach abstract concepts in physics.

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