Analysis of student’s learning achievement using PhET interactive simulation and laboratory kit of gas kinetic theory

C E Rustana1*, W Andriana1, V Serevina1, D Junia2

1Physics Education Program, Faculty of Mathematics and Natural Science, Universitas Negeri Jakarta, Jl. Rawamangun Muka No 1. Jakarta Timur, Indonesia, 13220
2Physics Program, Faculty of Mathematics and Natural Science, Universitas Negeri Jakarta, Jl. Rawamangun Muka No 1. Jakarta Timur, Indonesia, 13220

*Corresponding author: ce.rustana59@gmail.com

Abstract. This Quasi Experimental research aims to analyze the learning achievement of grade XI students of Public Senior High School in Bekasi, West Java-Indonesia. Two experiment science classes were selected as samples by using purposive random sampling. The 1st sample class was taught using laboratory kit activity; whirls the 2nd sample class was using PhET interactive simulation. The data was collected using written test to measure students’ achievement and then statistically analyzed using t-test to determine the hypothesis either be accepted or not. The normal distribution and homogeneity tests were also applied to know that the data was normally distributed, and all the variances were homogeneous with level of significant >0.05. The t test result indicated that the value of $t_{calculation} (3.052)$ was greater than and $t_{Table} (1.667)$ that shown that there was a significant difference between the learning achievement of class 1 and 2 with mean value of 70.85 and 63.26, respectively. In conclusion that learning process using PhET interactive simulation provided higher students’ achievement compared to those class which apply laboratory kit activity of gas kinetic theory.

1. Introduction

Teacher-centered learning tends to be monotonous and less involving students in discovering the concept in learning process which provide further impact on the students’ learning achievement. Therefore, a teacher-centered learning is not effective to be applied in learning and teaching process of physics. For it, teachers should apply an appropriate learning method for each related physics topic to develop understanding of pupil that could be indicated by students’ learning achievement. The laboratory kit activity might be assumed to be a proper method used by teacher in facilitating students to learn physics actively for increasing students’ learning achievement. By applying experiment learning method, the students are hopefully can be able to develop their understanding of Physics concept through scientific approach activity that support students to discovery and solve problem by themselves. However, lack of laboratory equipment and teacher skills as well as time constrain, the teachers are very seldom or many cases they not be able to apply experiment learning method in their class. However, the development of information and communication technology (ICT) has been
intensively supporting the development and application of multimedia in education. PhET interactive simulation is an example of multimedia application in education for hopefully supporting students’ understanding of Physics concept that may be measured through students’ learning achievement. For this reason, the research was designed to analyze the students’ learning achievement for those are taught by using experiment learning method with PhET interactive simulation and laboratory kit of gas kinetic theory matter.

2. Methods
Quasi experimental design with Nonrandomized Control Group Pretest-Posttest Design was applied in this research. Quasi experimental design is a research in where researcher cannot fully control the used sample. Each sample was given a treatment according to independent variables. Independent variables of this research were students’ learning process using experiment method with laboratory kit (Experiment Class 1) and learning process using experiment method with PhET interactive simulation (Experiment Class 2). While, dependent variable of this research was students’ learning achievement. A pretest was conducted for each class sample prior to learning treatment to know initial condition of samples followed by learning process applying experiment method for each class sample. In the end of learning process, the posttest was carried out for each class sample in order to know student’s achievement. Pretest and posttest instruments for collecting data were tested to know the validity, reliability, level of difficulty and discrimination power using Microsoft Office Excel. T test was used to analyze the different between student’s achievement of class sample applied experiment method with laboratory kit and PhET interactive simulation. We extensively test and evaluate each simulation to ensure educational effectiveness. These tests include student interviews and observation of simulation use in classrooms.

3. Result and Discussion
3.1 Documentation of learning process
The following figure indicated the class activities for both experiment classes (class experiment 1 and class experiment 2).

| Experiment Class 1 | Experiment Class 2 |
|--------------------|--------------------|
| Figure 1(a). Demonstration | Figure 1(b). Demonstration |
| Figure 2(a). Observation | Figure 2(b). Observation |
3.2 Description of data
The Microsoft Office Excel was used to validate instrument for collecting the data (pretest and posttest). The calculation shown that the validity of instrument is categorized sufficient. The first step of this research is giving a pretest to each class sample prior to learning process. The pretest result of each class is given in table 1.

**Table 1.** Pretest results of experiment class 1 and experiment class 2

| Class            | Experiment 1 (Lab Kit) | Experiment 2 (PhET) |
|------------------|------------------------|----------------------|
| Number of students | 34                     | 34                   |
| Minimum score    | 30                     | 30                   |
| Maximum score    | 50                     | 60                   |
| Average          | 40                     | 40.29                |
After a learning treatment was given to each class, a posttest was conducted to know students’ learning achievement. The posttest result is indicated in table 2.

| Class        | Experiment 1 (Lab Kit) | Experiment 2 (PhET) |
|--------------|------------------------|---------------------|
| Number of students | 34                     | 34                  |
| Minimum score | 50                     | 50                  |
| Maximum score | 85                     | 85                  |
| Average      | 63.26                  | 70.85               |

3.3 Analyzed Result
Normality test using Chi-Square test indicated the data are normally distributed. In this case, the calculation of $X^2$-count for experiment class 1 and experiment class 2 are 9.93 and 8.43 with the Degree of Freedom 5% are significant for $X^2$-table of 11.070 which was bigger than $X^2$-count. It can be understood that both data of experiment class 1 and experiment class 2 are normally distributed as shown in table 3 below.

| Class        | $X^2$-count | DK | $X^2$-table | df  | Status |
|--------------|-------------|----|-------------|-----|--------|
| Experiment 1 | 9.93        | 5  | 11.070      | 5%  | Normal |
| Experiment 2 | 8.43        | 5  | 11.070      | 5%  | Normal |

However, in order to find out whether data collected is homogeneous or not, the Fisher test was used to understand the homogeneity of data. According to the calculation, variance of experiment class 1 and experiment class 2 are 81.39 and 85.58. Since F-count (1.051) is bigger than F-table (2.39), it can be identified that the data is homogeneous as indicated in table 4.

| Class        | $S^2$-count | F-count | $X^2$-table | Status    |
|--------------|-------------|---------|-------------|-----------|
| Experiment 1 | 81.39       | 1.051   | 2.39        | Homogeneous |
| Experiment 2 | 85.58       |         |             |           |

T-test was used to examine the hypothesis to find out whether $H_0$ is rejected or accepted. The hypotheses are:
- $H_0$: $\mu_1 = \mu_2$ (there is no difference between posttest average result of experiment class 1 and experiment class 2)
- $H_1$: $\mu_1 \neq \mu_2$ (there is a difference between posttest average result of experiment class 1 and experiment class 2)
T-test calculation shown that t-count is 3.05 is bigger than t-table (1.669) with 5% significance. It means that $H_0$ is rejected and $H_1$ is accepted.

The analysed result indicated that the average of students’ achievement of experiment class-1 (Laboratory activity) was 63.26 in which was significantly less than the average of students’ achievement of experiment class-2 (PhET interactive simulation) that was 70.85. It described that the students were taught with experiment method using the PhET interactive simulation had better learning achievement compared to those who were taught using experiment method with laboratory kit activity especially for gas kinetic theory. This is in agreement with the results of the research by Rahayu, et.al. [1] which indicated there was positive impact the use of virtual media on students’ achievement. The students in experimental class-1 (laboratory activity) that were using Physics laboratory kits need to tightly follow direct instruction based on teacher guide or laboratory manual. Errors in assembling laboratory tools, it caused students to fail in carrying out laboratory work. The students also sometimes found difficulties in analysing data due to a lack of data accuracy. Inaccuracy in collecting data during laboratory activity, it made the students must repeat the experiment several times and spend more time. Piaget [2] described that educational researchers have found that with direct instruction causing students not be able to engage as scientist in doing their school work as a scientist. Instead of investigating, exploring, asking questions, making connections or deducing the rules, the students are only answering what has been asked, transfer and retaining very little. Such a tightly guided activity will prevent students from provoking deep thinking and learning as well as able to properly do their work since underprepared and in hurry; so they are not able to know how to be a scientist or do not care in discovering the physics for themselves. As mentioned by Adam [3] that recent studies exposes that appropriate scaffolding of the material is needed in helping students to build up a mental framework about concepts for constructing their own understanding concept within that mental framework. It all be assumed will negatively impact on understanding the concept of subject their learned and at the end it will impact the students’ achievement as indicated by the result of this research.

However, the PhET interactive simulations made students were observed easily to collect data and to minimize the mistaken in collecting data as well as to analyse the data since all the measured variables can automatically be displayed in the computer screen during the simulation process. The students have more time to learn and to understand the topics that they learnt by repeating the activity in their homes because of the PhET interactive simulation can be installed on their own PC or laptop. The students also showed more enthusiasm and actively involved in their learning by applying the PhET interactive simulation during the learning process. They are happily noticed in conducting experiment activity by using the PhET interactive simulation. It can be observed that implementation of the PhET interactive simulations in the students’ learning provided them with opportunity for having fully engagement as scientist-like exploration. As mentioned by Adams [4,5] that the PhET provided a high degree of interactivity in terms of user control, dynamic feedback, and multiple representations. It was in agreement with Lambert and McCombs which described that the positive learning experiences are facilitated through increased opportunities due to active participation and increased access to learning resources. Bransford [6] mentioned that the research on learning indicated that students requiring the main ideas for building up knowledge through an active process in thinking not only doing where students are active sense makers.

Accordingly, the PhET interactive simulation can effectively be used as an alternative approach to facilitate students learning for helping them to identify what is important and helping them to be able to build a mental framework for examining the phenomena in developing conceptual understanding of the science resulting greater and deeper learning of scientific concepts. It can be shown from the result of result that the students applying the PhET interactive simulation had better learning achievement compared to those utilized the science laboratory equipment or science laboratory kit in learning kinetic gas theory. Applying the PhET interactive simulation on students learning will provide
possibility to improve the learning achievement of students. So, the PhET interactive simulation can rationally be recommended to be used for having a better students’ participation and physics’ learning achievement for due to unavailability of laboratory kit at the schools which are more expensive to purchase and time consuming to use compared to the PhET interactive simulation. Furthermore, the use of PhET active simulation was highly suggested to be utilized by Physics teachers for improving education as supported by Jonassen and Reeves [7] as well as Kent and McNerney [8] that supporters of technology implementation have argued that computer technology can be effective in changing traditional centred teacher to a more constructivist student-centred classroom.

4. Conclusion
Research’s result shows that there is a difference between learning achievement of experiment method class using laboratory kit and PhET interactive simulation in gas kinetic theory matter. Posttest result of experiment method class using PhET interactive simulation is higher than posttest results of experiment method class using laboratory kit. Researcher also find that use of PhET interactive simulation can be able to increase students’ motivation to learn. PhET interactive simulation also facilitates students to collect experiment data very well. Meanwhile, in experiment method class using laboratory kit, there are some groups which have a problem in data collection during experiment. Inaccuracy during experiment resulted in failure of data collection, so that students could not be able to make a proper conclusion of experiment result that will provide them with misunderstanding of the concept of kinetic gas theory. The expanded of sample to cover a number of senior high schools in Bekasi and the size effect can be measured to understanding the contribution of the learning process using PhET interactive simulation can be identified for the future research in having general and depth conclusion of students’ achievement as whole.

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