The critical thinking effect of the computer simulation in the physics teaching and learning

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The critical thinking effect of the computer simulation in the physics teaching and learning

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Abstract. Critical thinking skills (CTS) are essential learning outcomes. The development of computer simulation applications is so fast need to be utilized in learning for improving CTS. This study aims to find out the effect of computer simulation, in this case, PhET simulation to the CTS in physics learning for the subject of Work and Energy. This study was conducted on 8th-grade high school students in Yogyakarta, Indonesia. The research method used was posttest only controlled group design. The control group and treatment group each consisted of 32 students. The learning for the treatment group was arranged in the form of a practicum using PhET simulation for 10 hours conducted in 5 meetings. The CTS was measured with essays covering five questions that had been tested for item discrimination, the degree of difficulty, validity, and reliability. The analysis technique used was ANOVA with the margin of error of 5%. The results of this study show that learning performance (CTS) by using computer simulation tends to better (77.89) compared with conventional learning (64.75) after the learning process.

1. Introduction

In physics learning, students sometimes experience some difficulties and misconception in understanding the particular phenomenon [1,2,3]. It becomes an obstacle in the learning process; including in learning the concept of Work and Energy which is abstract in the 8th-grade students. Learning by demonstrating on the particular level can help the learning performance. However, the existence of complex variables results in the demonstration which does not always match the theory students learns [4].

The development of technology has opened opportunities for various learning media to manipulate multiple natural phenomena by focusing on particular aspects [3,5,6]. PhET simulation (PhET) is one of the computer simulations developed to meet the needs [7,8]; including in understanding the concept of Work and Energy. This simulation was generated by using a specific mathematic model to accurately figure out the particular phenomenon by controlling various unexpected variables. Through this simulation, students can visualize the objects and the process which can't be controlled in the real condition [8]. Thus, students can experience scientific activities such as hypothesizing, experimenting and synthesizing in the solving problem related to a phenomenon [5,9].

Numbers of researchers in science learning have utilized PhET by using various learning strategies [1,2,3,4,5]. These researchers showed that using PhET can improve multiple aspects of learning performance such as motivation, understanding, misconception and active learning. As current learning demand, learning performance related to higher order thinking skills become immensely valuable [10,11]. One of them is critical thinking skill (CTS). Unfortunately, in Indonesia the number of research related to science learning particularly physics learning which is utilizing PhET to improve learning skill is relatively low. It becomes a significant part of this article to contribute to science learning field.

Student's scientific activities in interacting through computer simulation can encourage the CTS improvement. The fundamental idea of PhET development is using constructivist learning perspective. PhET provide dynamic access to multiple representations, make the invisible visible, scaffold inquiry, and allow for safe and quick access to various trials while being engaging and fun for students and teachers [12,13].

By considering the physics learning problem on the subject of Work and Energy and the opportunity to utilize the computer simulation for learning, the problem formulation of this article is whether there is an influence of PhET utilization on the subject of work and energy towards the CTS improvement.

2. Method

2.1. Participants

This research was conducted to 8th high school students in the physics teaching and learning on the subject of Work and Energy in the academic year of 2016/2017 in Yogyakarta Special Province, Indonesia. The school where the research is conducted is not a favorite school. It is located in suburban area with middle to low of economic level of the student's background. This research was done at that quality level of school to give broader impact to similar schools as the number of those schools is higher than the favorite ones.

2.2. Research design

The research is a pretest-posttest controlled group design research. Since student's randomization was technically impossible, randomization was only conducted when choosing the class as control group and treatment group from six classes (201 students). Sampling for control and treatment group was taken by using simple random sampling technique. Control and treatment class each consists of 32 students. Students who were considered in the research were only ones entirely attended all learning activities. Ones who didn't fully participate on the all activities were taken out from the research sample.

In control group, students were taught with the conventional method by using lesson books at school while in the treatment group, and students were taught with PhET by using scientific learning strategies (observing, questioning, reasoning, experimenting, and networking). The research variables were learning strategy as the independent variable and critical thinking skill as the dependent variable.

2.3. Material and learning activities

The simulation used for work and energy learning was The Ramp 1.07 taken from https://phet.colorado.edu/en/simulation/legacy/the-ramp which runs offline on the computer. The screenshot for the simulation is shown in Figure 1.

In conducting learning, the teacher prepared a lesson plan which had been validated, so it met the learning objective. The learning stages undertaken in the treatment class was based on scientific approach learning as follows:

2.3.1. Observing. In this stage, the teacher explained how to run the ramp downloaded from PhET. Next, students tried by themselves to identify what they can do with the simulation application.

2.3.2. Questioning. Students discussed with other friends or searched for other additional information to find various alternative solutions for particular cases given by the teacher. Therefore, students could estimate the situation of the phenomenon of the assigned cases.

2.3.3. Reasoning. By frequently using the simulation, students experiment various alternative solutions for particular cases. As a result, students got the new understanding to explain the given cases.

*2.3.4. Networking. Base*d on the experience, students shared information with all members of the class to get shared understanding; it can be in the form of categorizing, associating or relating phenomenon/information, finding a pattern, and concluding.

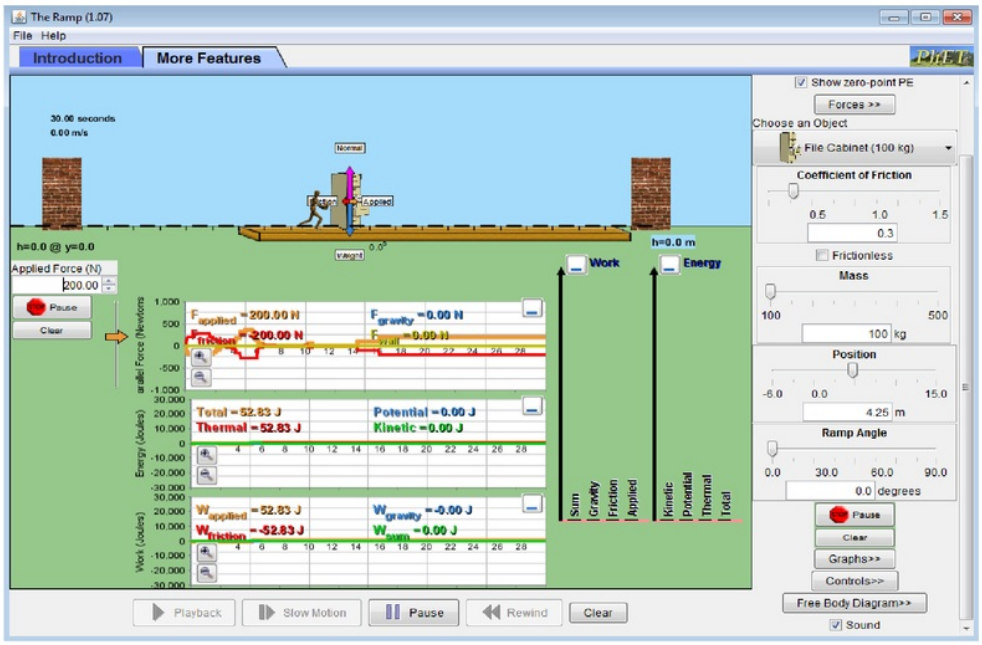

Figure 1. The screenshot of the Ramp (1.07) as the simulation app

2.4. Data collection and analysis

The data of CTS was taken by using five essay questions. The questions were scored based on the stages of solving a complex problem related to work and energy. The questions were developed by referring taxonomy bloom on the level of C3 and C4. Previously the questions had been tested on item discrimination, the degree of difficulty, validity, and reliability.

The data analysis used parametric statistics by considering data normality and homogeneity. Next, the data was processed by using one way ANOVA to find out the significance of the learning strategy influence towards the CTS.

3. Result and discussion

3.1. Result

The measurement data of the CTS of control and treatment group was next processed with descriptive statistic and analysis of variance. Table 1 shows the effect of the descriptive statistic.

Table 1. Descriptive for the control and treatment group

	N	Mean	Std. Deviation	Minimum	Maximum
Control Group	32	64.7500	9.25272	54.00	77.00
Treatment Group	32	77.0313	6.66471	62.00	85.00
Total	64	70.8906	10.11382	54.00	85.00

From Table 1, it can be seen that the average score of CTS for treatment group (70.89) is higher than the control group (64.75). Also, the standard deviation of treatment group tends to be narrower (6.66) than the control group (9.25). The two findings become significant on the effect of learning by using PhET in the class. There is a tendency that treatment group students who study work and energy by using PhET tend to have better CTS after learning. Besides, in the whole group, the distribution of the CTS seems to be more even among students. This effect can be seen from the standard deviation of treatment group which is smaller than the control group (students taught conventionally). The difference of standard deviation also shows that at the end of learning both groups become heterogeneous groups. This heterogeneity can be seen from the result of the test of homogeneity of variance with Levene statistic (i.e., $p = 0.002 < 0.05$).

F-test with ANOVA on the margin of error of 5% was conducted to find out if there is a difference of CTS score between control and treatment group. The dependent variable is CTS score, and the independent variable is learning strategy. The F-test result is shown in table 2.

Table 2. Analysis of Variance (F-test) for the means of the critical thinking skills score.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2413.266	1	2413.266	37.118	.000
Within Groups	4030.969	62	65.016		
Total	6444.234	63			

From the result of F-test, it can be seen a significant difference in the average score of the CTS between control and treatment group. In conclusion, the learning outcome in this case CTS with PhET sim is higher than the conventional one.

3.2. Discussion

As previously mentioned, this research aims to find out the effect of physics learning on the subject of work and energy by using PhET. The learning process conducted to students who learn by using PhET followed the scientific approach learning procedure. The implementation of the learning could run as planned. From the statistical analysis, students who were taught by using PhET shows the better result on higher order thinking skills (CTS).

Another finding is that more similar CTS occur in students. Student's interaction during the learning seems to have the good effect on the CTS. It can be seen that distribution of student's CTS tends to be evener. This finding shows that learning strategy which was carried out could encourage a better student's interaction. This interaction furthermore gives effect towards various aspects. One of them is an opportunity to share knowledge, so student's understanding towards one phenomenon becomes more similar. This result parallel to the othe research that the deviation among students become closer [14,15].

Another explanation related to the two findings in learning is explained with the concept of Edgar Dale's of experience wherein learning by using PhET students do activities by involving skill, attitude and knowledge [16,17] when running the Ramp application to solve particular problems. During the learning process, students experience some stages of scientific learning from observing, questioning,

reasoning, and networking. Those activities were done both individually and in the group. As a result, in learning, students do activities that involve more domains. This process is the reason for the increasing skills besides the existence of student's interaction. Facing the penetration of mobile technology on learning in Indonesian education [18,19], this result can be combined to better improvement of learning performence in science learning.

There are several limitations related to this research, particularly on external validity. In this research, sample randomization was not conducted. Control and treatment class were formed by choosing the existing courses. This choice was based on the assumption that they had same characteristics and were normally distributed. In this research, the similar learning process was carried out and controlled by the validated lesson plan. Also, it has been ensured that sample never attended learning with the same strategy as applied in this research. In the next study, what needs to consider are to conduct pretest and choose several covariates to control other influence factors besides the observed variables.

4. Conclusion

This research finds out the influence of learning strategy towards CTS. The experimental strategy is learning strategy for the subject of work and energy on grade 8. Learning was done with scientific approach supported by PhET sim with the Ramp application. The result shows that students who were taught by using this strategy tend to have higher CTS after learning compared to ones who were conventionally taught. Students who were trained by using this strategy also tend to have more even CTS after learning. The limitation of this research can be improved by adding covariate on the research.

Acknowledgments

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