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The Critical Thinking Skills Impacts on the Utilization of PhET Simulation in the Flipped Classroom Setting

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Abstract. **This study examines the impact of flipped classrooms on problem-based learning assisted by PhET simulations in improving students' critical thinking skills. The design of this study was a pretest-posttest controlled group design. The subjects were 33 students for each group who learned the parabolic motion. In the experimental group, before doing activities at school, students have studied PhET simulations related to the parabolic motion on various variables in the simulation. When at school, the teacher applied problem-based learning related to the material that the worksheet facilitated. At the end of learning, the students were given a test to measure critical thinking skills. The critical thinking skills were measured using essay questions. The questions had been validated for the level of difficulty and determination level. The analysis technique used was the t-test. The results showed that there were significant differences between the two groups. These findings indicate that the application of this model can improve students' critical thinking skills.**

Keywords: flipped classroom, PhET simulation, critical thinking skills

INTRODUCTION

The utilization of information and communication technologies in everyday aspects of life in the 21st-century demanded the change of competencies needed in the workplace. The graduates of high school, diploma, or higher education are still less competent, specifically in terms of their critical thinking [1]. Critical thinking skills (CTS) become one of the skills needed at work in the 21st-century [1]-[4]. CTS is a skill that allows a person to solve the problem in logical ways [1], to create and perform assessments and draw conclusions based on evidence [5], to reflect rationally, or to evaluate information to get a right decision [3],[6]. Critical thinking is a reflective thought which includes senses before deciding what to do [7]. The participants of the current study are students who suppose to have critical thinking skills to be able to compile, disclose, analyze, or resolve problems, [8],[9]. Therefore, the skills need to be socialized and trained at schools to equip students to face the future and to meet the 21st-century demands [3].

Teachers of physics are still experiencing difficulties in designing the strategy of learning because of the limited time to teaching in the classroom. So, teachers tend to use lecturing methods, resulting in the students' low critical thinking ability [10]. Students tend to experience difficulties in understanding a specific phenomenon [11]. It has become obstacles in the process of learning, including in studying the concept of parabolic motion. One approach proposed to train the students' critical thinking is problem-based learning. The learning process uses certain issues as a context to learn CTS, including the process of problem settlement [3]. In this learning model, the students not only master the concept but also develop ideas through language verbally. It is due to the fact that verbal communication is one of the essential factors to train the students' critical thinking skills and to develop self-reliance [12].

One of the learning models proposed to deal with the time limit is the flipped classroom. The flipped classroom is a learning model that reverses teaching methods in the classroom [13],[14]. The concept of the class is that anything done in the classroom can now be done at home as well. On the contrary, what is done at home can also be done at school [15],[16]. The model is moving the learning (such as video) to the outside of a formal class. Furthermore, the use of formal classrooms for students is to perform activities of collaborative and interactive, which is relevant to the matter of learning, such as experiments, presentations, and discussions [17],[18]. The benefit of this type of learning is the students can easily repeat video learning [15] and explores the material of learning by themselves or in a group outside the classrooms [19]. Through video, the students are interested in learning physics, training the ability to think about any phenomena they found in their everyday lives [20]. The flipped classroom is a potential media to support teaching and learning activities. Learning

videos that are designed can be used for learning and assessment [21].

The PhET simulations could be a solution to help the students in understanding abstract physics concepts. It can visualize objects and processes that are not able to be controlled in a manifested condition [11]. It can also be a solution for schools with limited means of experimental physics but have adequate computers to support learning processes. PhET simulation allows learners to connect the phenomena of real-life and knowledge. In the end, it can deepen the students' understanding and interest in the science of physics [22]. Students can hypothesize, experiment, and synthesize in solving a problem that is associated with a phenomenon; it is more exciting and fun to boost critical thinking skills. Unfortunately, in Indonesia, the amount of research related to the study of physics which utilizes *PhET* to improve the skills to think critically relatively low [11].

The current research objective is to determine the effect of the application of flipped classroom in problem-based learning assisted by *PhET* simulations on improving students' critical thinking skills and find out whether there is a different effect between the application of flipped classroom in problem-based learning assisted with PhET simulation and conventional learning.

METHOD

The current study is an experimental research. The study design uses a pretest-posttest controlled group design. The two grouos are given different learning strategies. The controlled group is treated using conventional learning, while the experimental group is treated using the flipped classroom based on problem-based learning supported by PhET.

The population of the research is the tenth-grade students of a public senior high school in West Papua. The sample in this study consisted of two groups, namely the controlled group and the experimental group. The independent variable of this study is the application of flipped classrooms in problem-based learning with the help of PhET simulation. The dependent variable is critical thinking skills.

The instrument is a test in the form of an essay. This test can reveal, construct, analyze, synthesize, and evaluate reasons [23],[24]. The tests used are guided tests consisting of 12 indicators to think critically, and are summarized into five groups of CTS, namely elementary clarification, essential support, inference, advanced clarification, and the strategies and tactics [23]. Techniques of analysis are the technique of statistical analysis of t-test (independent sample test) and test N-gain. Assumptions met before carried out a test is explanatory variable distributed as normal and homogeneous. The data has a small error standard.

RESULT & DISCUSSION

Based on the data obtained, the following description of the value of critical thinking skills in the controlled class and experimental class is as shown in table 1.

Table 1. Description of the CTS

	N	Mean	Standard Deviation	Minimum	Maximum
Controlled Group	33	66.56	8.25	55.65	84.88
Experimental Group	33	79.73	7.27	68.95	94.65

The T-test is used to determine whether there are differences in effect between the application of the flipped classroom on problem-based learning supported by PhET simulations and learning a conventional. It turned out that P-value is (0.0000063) <0.05. It means that there are differences in the effect between the application of the flipped classroom on problem-based learning supported by PhET simulations and conventional learning.

Table 1 shows that the average value of the experimental class's critical thinking skills (79.73) is higher than the controlled class (66.56). The standard deviation of the experimental class (7.27) tends to be smaller than the controlled class (8.25). Based on the two things mentioned, the students in the experimental group undergoing treatment flipped classroom on problem-based learning supported by PhET simulations tend to have better CTS than the students in the controlled group experiencing conventional learning. This finding is supported by the results of the N-gain of the CTS test. The mean of experimental class N-gain is 0.65, more substantial than the mean of controlled class N-gain (0.41), although both are still in the medium category.

In addition, viewed from each indicator of critical thinking skills, the results obtained can be seen in Figure 1.

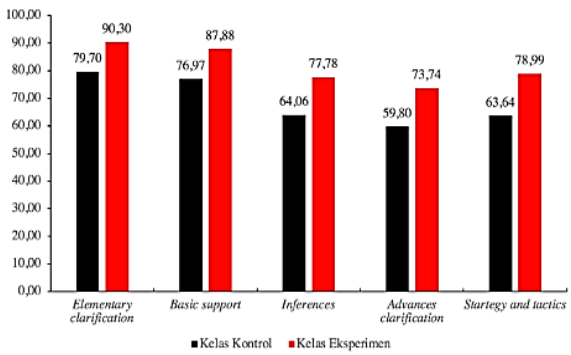

Figure 1. The value of each group of indicators of CTS

Figure 1 shows that the values for the five groups of critical thinking skills indicators in the experimental class are more significant than the controlled class. The highest elementary group indicator for the controlled group is 79.70, while the experimental group is 90.30. In contrast, advances clarification became the indicator group with the lowest value of the controlled group is 59.80, and the experimental group is 73.74.

In the controlled group, conventional learning is applied, while the experimental group applied the flipped classroom based on problem-based learning supported by PhET simulations. The participants are students in which both classes are given a parabolic motion topic. The implementation of the learning goes in accordance with the plan. In the experimental classroom, a week before learning in the classroom, the participants shared video learning through smartphones. Participants are asked to watch a video lesson which contains material about parabolic motion at home before learning in the class [16],[25],[26].

Previous research has shown that flipped classrooms tend to influence the development of creative thinking skills [27]. The flipped classroom also proved to improve the ability to understand concepts [16], [20]. Problem-based learning effectively in developing the skills to think critically among participating students [3]. Learning by using PhET can improve the physics representation and critical thinking skills of students [28]. From the results of the analysis of the statistics, there are differences in the effect of the application of the flipped classroom on problem-based learning supported by PhET simulations with conventional learning. Students taught using the flipped classroom based on problem-based learning supported by PhET simulations (the experimental group) showed an increase in the CTS. It is better than the students taught using conventional learning in the controlled group.

Besides, the experimental group's standard deviation was narrower compared to the controlled group. It means that the distribution values of CTS among the experimental group is more evenly distributed than in the controlled group. It happens because the interaction and communication among learners in the experimental group are interwoven compared to the controlled group. Students in the experimental group have many opportunities to work in groups [29]. They also share knowledge in comparison to the controlled group, thus enabling the students' understanding of a phenomenon becomes more similar [11].

The experimental group has better values than the controlled group within each group indicator of the CTS. The indicators of CTS that has the highest value for both the experimental and the controlled groups. The students' mastery in giving explanations is better because the planted concept of the base is strong through video learning and is given prior to the learning process in the classroom. The students watch the learning video and do all the instructions given by the teachers. Teachers provide instruction so that students can press the pause to stop the video while writing down questions being asked. The students can press the button forward or backward to advance or rewind the video while writing down a summary of the material and answer questions from the video. In the beginning, students were asked to collect the summary results. After that, the teacher gave a quiz through the video in which the answers could be found in the video [30],[31]. Such a lesson video can be watched by the students to develop and form independent study [16],[25],[26]. Additionally, the students can build a better understanding of the material since they can repeat watching videos several times [20],[32],[33]. This result is different from conventional learning in the controlled group. Teachers give explanations about the materials. The students asked questions, the teacher responded, and then the teacher gave examples relating to everyday life's phenomena, then provided practices and home works.

CTS group indicators, which is necessary to support the experimental group, is higher compared to the controlled group. It can occur because communication among participants as well as between the participants and teachers intertwined increasingly. Another result is in the increase of involvement and activeness of participants in learning. The students become more comfortable and believe in themselves because they already have preparation before the lesson in the class [34],[35]. The learning process also becomes more alive. Participants can build skills essentially through activities of problem-solving in a collaborative such as experiments, presentations, application, and discussion. In the experimental group, the students used PhET simulations guided by pieces of work. The participating students work and discuss together in a group. They also wrote the observation result, analysis, and discussion of the work, and then present the results of an experiment in front of the class The PhET simulation of parabolic motion can be seen in Figure 2.

Teachers, as facilitators, answered questions from learners, assisted and guided learners, provided feedback [26],[31], and directed the classroom activities [20]. It allows learners to develop their critical thinking skills[33]. The learning process is centered on students, as expected in the 21st-century learning [11],[14].

The CTS indicators that have the lowest scores in both experimental and controlled groups are advanced clarification, inference, strategies, and tactics. The participating students have been able to conclude the experiment and learn various

activities. However, some students still need guidance from the teachers. Students also face challenges to explain or to set strategy and tactics to resolve a problem given.

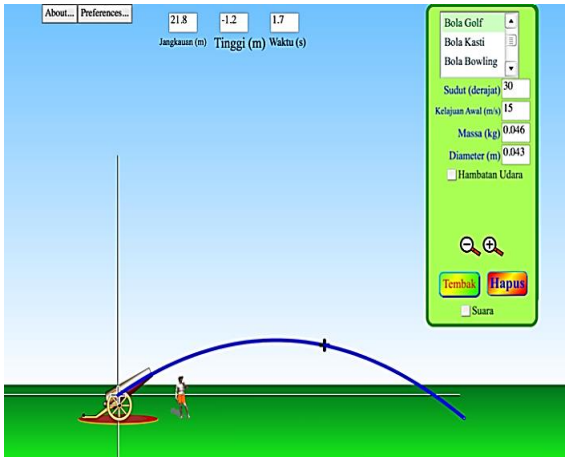

Figure 2. PhET simulation of projectile motion

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CONCLUSION

Based on the results and discussion, there are differences in the effect of application between the flipped classroom based on problem-based learning supported by PhET simulations and conventional learning. The participating students joining the flipped classroom based on problem-based learning supported by PhET simulations tend to have better CTS than those joining traditional learning.

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