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The Effect of Scaffolding Approach Assisted by PhET Simulation on Students' Conceptual Understanding and Students' Learning Independence in Physics

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The Effect of Scaffolding Approach Assisted by PhET Simulation on Students' Conceptual Understanding and Students' Learning Independence in Physics

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Abstract. The aim of this study was to investigate the effect of learning with scaffolding approach assissted by PhET simulation on students' conceptual understanding and students' learning independence. Research design using experimental design with one group pretest posttest study. The sample was 27 grade 10th senior high school students. Sample was chosen by purposive sampling technique. A test utilized as the pretest and posttest to collect data students' conceptual understanding. Students also observed during the interventions to know students learning independence. Data analysis utilized quantitative and qualitative analysis techniques. The results of this study indicated that there is difference between students' conceptual learning before and after learning in the scaffolding approach assisted by PhET simulation. However, this difference was not have a significant effect on students' conceptual understanding. It also revealed that learning in the scaffolding approach assisted PhET simulation has effect on students' learning independence. Students' learning independence were in good enough and good category. Besides, students activities were increased during learning. Students became more active in seeking knowledge and interaction among students were increased. It provides communication and collaboration activities. The scaffolding and simulation were appropriate with the Indonesian curriculum and 21st century learning. These results suggest that within high school, scaffolding approach with PhET simulation can be use to improve students' learning independence.

Keywords: Scaffolding approach; PhET simulation; Students' conceptual understanding; Students' learning independence.

1. Introduction

Indonesian curriculum called "Kurikulum 2013" that has been revised has goal in physics teaching. The goal is to promote students' understanding and application of scientific knowledge. Outcome of this goal is students become good thinker which have higher order thinking skills [1]. However, students often have misconceptions about physics concepts [2]. This shows students have low conceptual understanding. Kurikulum 2013 also demands the development of students' affective [1]. Some studies have found that students' learning independence influence students' success in learning [3],[4]. Students' learning independence characterized by attitudes such as responsibility, self-confidence, initiative, independence, self-evaluation, discipline, and students plan their own learning

[5],[6]. Therefore, improving students' affective especially students' learning independence are important.

One of educational objective states that 21st century learning must integrate communication and collaboration into learning activities [7]. 21st century learning has positive impact on students' 21st century skills [8]. However, learning activities in the science classroom are usually teacher-centered [9]. It means, activities or participation of students in learning still low. In addition, the learning showed the completeness of learning material regardless of students' mastery of concepts [10]. As a result, communication and collaboration activities did not occur in the science learning.

A number of studies have found several advantages of using scaffolding approach in learning. The application of the scaffolding approach could improve students' understanding [11]. Scaffolding also have positive influences soft skills which is collaboration [2], on students' motivation, students' mastery concepts [13]. Scaffolding could provide learning assistance for students [14]. Therefore, teacher scaffold need to be given during learning activities to improve students' understanding, affective, and skills [14],[15]. These findings suggest that scaffolding approach can be applied to improve students' understanding the concepts and students' affective. However, in these research, researchers only applied scaffolding approach without any learning media. The use of scaffolding approach with a learning media especially technology need to be discuss.

Scaffolding approach relates to the role of the teacher together with students in problem-solving activities [16]. Scaffolding conducted by provide assistance (scaffold/support/help) to students to complete learning tasks [17]. Assistance give to students so they can achieve abilities or skills that teachers expect. The scaffolds are temporary or decrease. The scaffolds is no longer given by teacher when students have achieve the ability [18]. Thus, it expect students will be able to complete learning tasks and acquire skills.

The scaffolding approach in learning can be applied through several levels of assistance by teachers include environmental provisions, explaining, reviewing and restructuring, and developing conceptual thinking. Each of these level has several examples of interactions that can be applied by teacher to assist students. Environmental provisions is the conditioning of the learning environment. This level carried out through interactions such as arranging seats, making groups of students, and classroom organization. Explaining, reviewing, and restructuring include interactions such as: (1) asking students to look, touch and what they see and think, (2) interpreting students' actions and comments, (3) using questions that are probing and prompting, and (5) asking students to explain and give reason. Then, in this level especially for restructuring can be applied by providing assistance in the form of: (1) proving meaningful contexts for abstract situations, (2) simplifying students' problems or tasks, (3) rephrasing students' conversations or comments, and (4) negotiating meaning [19].

Several physics material also require teacher to demonstrate physics concepts. However, not all physics phenomena can be domonstrated by teacher directly because of the limitations of media for demonstration and experiment. Learning media for demonstration and experiment was not always available [20]. Computer technology progress has attracted the attention researchers to use simulation as a learning media [21],[22]. Some studies have shown the benefits of using simulation in learning [23]-[25]. This studies have found that simulation can enhance learning [26] such as increasing knowledge of science content and process skills and facilitating students' conceptual changes [27]. Simulation in particular PhET simulation more effective if applied as a learning supplement or support [27]. Thus, PhET simulation appropriate if integrate with scaffolding approach, demonstrating the concept of physics, and improving student conceptual understanding. However, the impact of using simulations with a learning approach as a main strategy in learning has not investigated. Furthermore, there are no learning material in Physics learning which use scaffolding approach with a simulation. Hence, the use of scaffolding approach with a simulations still need to be evaluate or investigate.

This study integrates the scaffolding approach assisted by PhET simulation in learning. PhET simulation on collision type on the topic of the law of momentum conservation applied as learning media. This simulation can operate using a computer so that technology carried out in the learning. This simulation contain collision experiment. It can help students to understand and prove the law of momentum conservation directly. The teacher can demonstrate law of momentum conservation and collisions phenomenon through this simulation. The physics concepts presented will be more real observed. Students understand the concepts more easily through this simulation. For this reason, the following research questions investigated are:

(1) Do the students who learn with scaffolding approach assisted by PhET simulation show better conceptual understanding?
(2) Do the students who learn with scaffolding approach assisted by PhET simulation show better learning independence?

The rest of this paper is organized as follow: Section 2 describes the proposed research method. Section 3 presents the obtained results and following by discussion. Finally Section 4 concludes this work.

2. Research Method

This research is experimental research. The study design of students' conceptual understanding utilized pre-experimental design with one group pretest-posttest study [28] as shown in Table 1.

Table 1. Research design

O_1	X	O_2

where O_1= pretest, O_2= posttest, and X= implemented scaffolding approach assisted by PhET simulation.

The experimental class utilized learning with a scaffolding assisted by PhET simulation. In learning activities, scaffolding conducted in the form of environmental provisions, asking student see and touch through collision lab of PhET simulation, and verbalize what they find from the experimental results. Students were given worksheet by teacher developed in particular for collision lab of PhET simulation. Student worksheet (called LKPD "Lembar Kerja Peserta Didik") specifically developed for this simulation.

The PhET (Physics Education and Technology) simulation utilized is collision lab that can be operated using computer. Collision lab simulation can be accessed from the website https://phet.colorado.edu/en/simulation/collision-lab [29]. Therefore, a technology utilized in this learning. This simulation contain experiment on collision between two balls (see figure 1). Students could experiment to prove the law of momentum conservation. This simulation could give experience and visualize phenomena unobservable to students. Students collected data from the collision lab and analyzed the result of the experiment in this experiment. They could manipulate data from PhET simulation such as mass, position, velocity, elasticity of collision. Simulation could give a chance for students to observe the differences in kenetic energy and momentum before and after collision. Students also can change the elasticity of collision in order to give information the differences elastic and inelastic collision (see Figure 1).

The LKPD developed based on collision lab simulation. The LKPD consisted of experiment objectives, experiment steps, table of results for elastic and inelastic collision, and discussion questions (see table 2). Table of results consist of table of results for elastic collision and table of results for inelastic collision. Students experiment five times in each collision. Magnitude of momentum was setting different for ball 1 and ball 2 in each collision. Students must complete the table for the momentum ball 1 and momentum ball 2, total momentum and kinetic energy before and after collision. Students analyzed data from the table of results to answer discussion questions. Discussion questions were given by teacher so students can analysis law of momentum conservation and the differences between elastic and inelastic collision. Discussion questions also facilitated communication and collaboration among students so that they can develop students' learning independence.

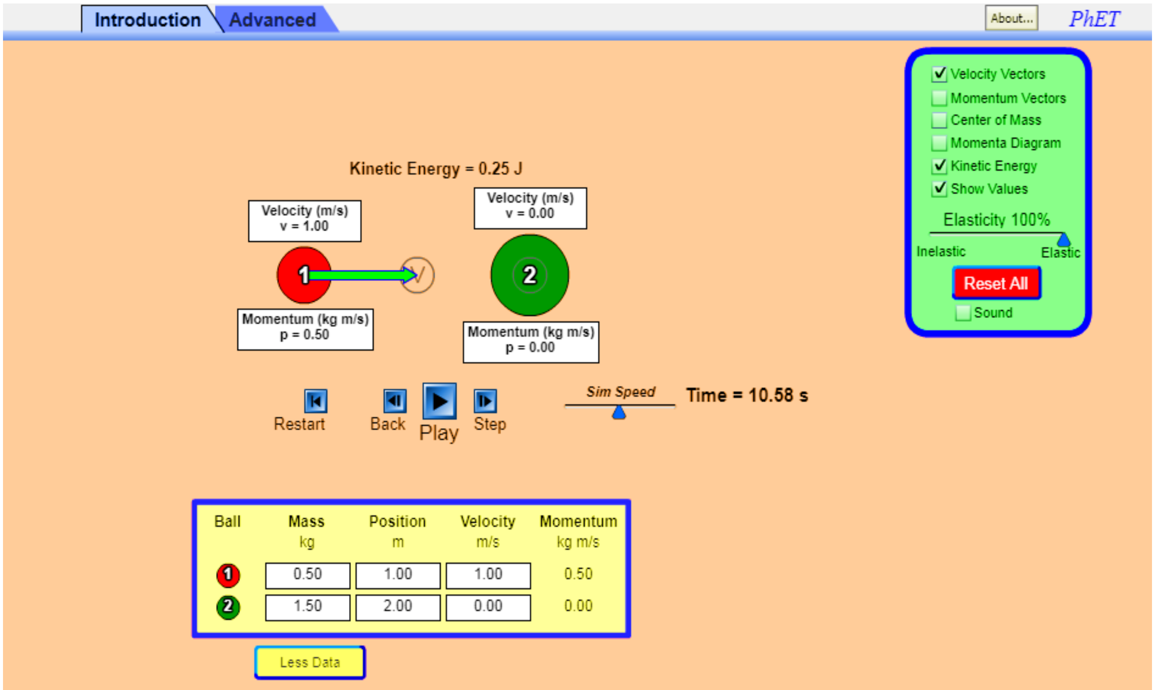


Figure 1. Collision lab PhET simulation [29]

Table 2. List of questions for discussion section on students worksheet

No.	Questions
1	According to experiments, what is the total momentum before and after the collisions on both balls?
2	How is the total momentum of the ball before and after the collision on the elastic collision?
3	How is the total kinetic energy of the ball before and after the collision on the elastic collision?
4	How is the total momentum of the ball before and after the collision on the inelastic collision?
5	How is the total kinetic energy of the ball before and after the collision on the inelastic collision?
6	What are the differences between elastic and inelastic collision? Give examples in everyday life?
7	State the law of momentum conservation!

Purposive sampling technique was used to decide sample [30]. Sample consisted of 27 students grade 10th in MAN 1 Yogyakarta state senior high school. The sample was selected because have not studied the law of momentum conservation and collisions. The research carried out with steps, namely: (1) conducting pre-research (observation of classroom learning); (2) formulating the research problem derived from pre-research results; (3) developing subject-specific pedagogy including lesson plan, student worksheet (LKPD), the law of momentum conservation handout; (4) developing measurement instruments for students' conceptual understanding and students' learning independence; (5) conducting validation of subject-specific pedagogy by experts; (6) revising subject-specific pedagogy and measurement instrument; and (7) implementation in learning using scaffolding approach with PhET simulation. The lesson plan was developed by integrating the level of scaffolding adapted from Angileri [19]. The implementation of the scaffolding approach with PhET simulation shown in table 4.

Data of students' learning independence has obtained by observation technique. There are four aspects of students' learning independence include self-confidence, responsibilty, initiative, and discipline. Students' learning independence instrument adapted from Arikunto [28]. Data of students' conceptual understanding has obtained conceptual understanding test. This test consists of 10 multiple choice questions regarding the law of momentum conservation and collisions. Indicator for questions in the test made based on Bloom's taxonomy of understanding aspect (C2) [31]. Students' conceptual understanding measured before and after learning. The purpose was to see an increase in students' conceptual understanding.

Research data obtained are scores of students' conceptual understanding and categories of students' learning independence. Descriptive statistics was used to analyze students' conceptual understanding. Analysis of students' learning independence done by calculated the scores obtained. Then determined the criteria of students' learning independence based on the scores obtained. The equation for calculated students' learning independence scores as follows,

$$Score\ of\ students'learning\ independence = \frac{total\ score\ obtained}{maximum\ score} \times 100\% \quad (1)$$

and students' learning independence criteria as follows,

Tabel 3. Students' learning independence criteria

Percentage	Category
76%-100%	Good
56%-65%	Good enough
40%-55%	Less good
<40%	Not good

(Arikunto, 2010)

Table 4. Scaffolding approach with PhET simulation based on learning objectives

Level of scaffolding approach	Description	Learning objectives
Level 1: Environmental Provisions	Organizing clasroom, arranging student seat in each group, giving motivation and apperception. Motivation and apperception - Teacher showed pictures of a car is crashing a truck, a rocket, and an airbag. - The teacher gave questions "What do you observe? How do you know where the car and are moving after a collision? How does rocket work? The teacher asked students to answer the questions.	Students' learning independence for self-confidence and initiative aspects.
Level 2: Explaining, reviewing, restructuring Includes interactions:		
- *Explaining*	Explaining the basic concept of the law of momentum conservation and collisions.	Understanding
- *See, touch, and verbalize*	Students conducted experiment with collision lab of PhET simulation. The teacher gave the opportunity to students to see, touch, and verbalize the concepts of the law of momentum and collisions directly.	- Understanding; developing students' conceptual understanding - Analyzing - Students' learning independence for self-confidence, initiative, responsibility, and discipline

Table 4. Scaffolding approach with PhET simulation based on learning objectives

Level of scaffolding approach	Description	Learning objectives
		aspects.
	LKPD provide discussion questions. Verbalization did through discussion and presentation of the results of the group at work.	- Students' learning independence for self-confidence, initiative, responsibility, and discipline aspects. - Analyzing - Distinguishing types of collisions.
	LKPD provide experiment steps and table of results that can be utilized by students in analyzing experimental results related to differences in types of collisions.	
- *Simplifying problems*	Helping students who have difficulty in completing discussion questions by simplifying the problems.	
Level 3: Developing conceptual thinking	Teachers and students together concluded learning activities regarding the law of momentum conservation and collisions.	Students' learning independence for self-confidence and initiative aspects

3. Results and Discussion

Physics learning in the material of law of momentum conservation applied scaffolding approach assisted by PhET simulation. In learning activities, students were given worksheet by teacher developed in particular for PhET simulation. Given scaffolding was in the form of three-level that is environmental provisions includes organizing classroom, arranging students seat in each group, giving motivation and apperception; explaining, reviewing, and restructuring includes explaining the basic concepts of law of momentum conservation and collisions, see and touch through PhET simulation, verbalize what they found from the experiment and simplifying problems; and developing conceptual thinking. The teacher and students concluded the law of momentum conservation together through discussed at level developing conceptual thinking. Students also discussed together to answer the discussion questions on LKPD about what they found from the experiment. This activities conducted to develop students' conceptual understanding and students' learning independence.

The study was conducted at students grade 10th MAN 1 Yogyarkata. The focus of the study was to find out the effect of scaffolding approach with PhET simulation on students' conceptual understanding and students' learning independence.

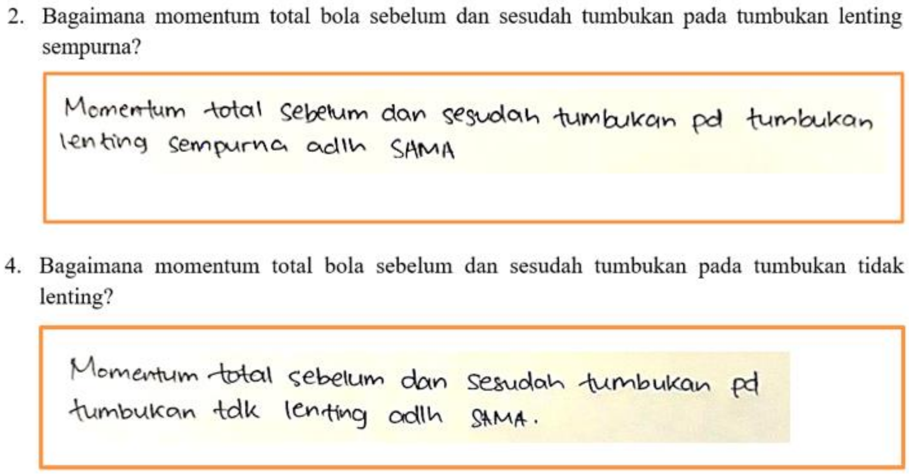
3.1 Students' conceptual understanding

The results of analysis for students' conceptual understanding can be seen in Table 5.

Table 5. Students' conceptual understanding

Test	Mean Score
Pretest	28,85
Posttest	32,69

Table 5 shows that there was difference in pretest and posttest scores of students' conceptual understanding. Students' posttest score was higher than the students' pretest score. However, this difference was not significant. Students have indeed understood the concept of the law of momentum conservation through the experiment using PhET simulation. Nevertheless, the depth of understanding of the concept has not given by the teacher. Students have only comprehended the concept through experiment and teacher's explaining in learning. Concept understanding test provide include a depth understanding of the laws of momentum conservation and collisions. On the other hand, the stages of giving students the practice problems to understand the concept deeper cannot be done well in learning activities.


2. Bagaimana momentum total bola sebelum dan sesudah tumbukan pada tumbukan lenting sempurna?

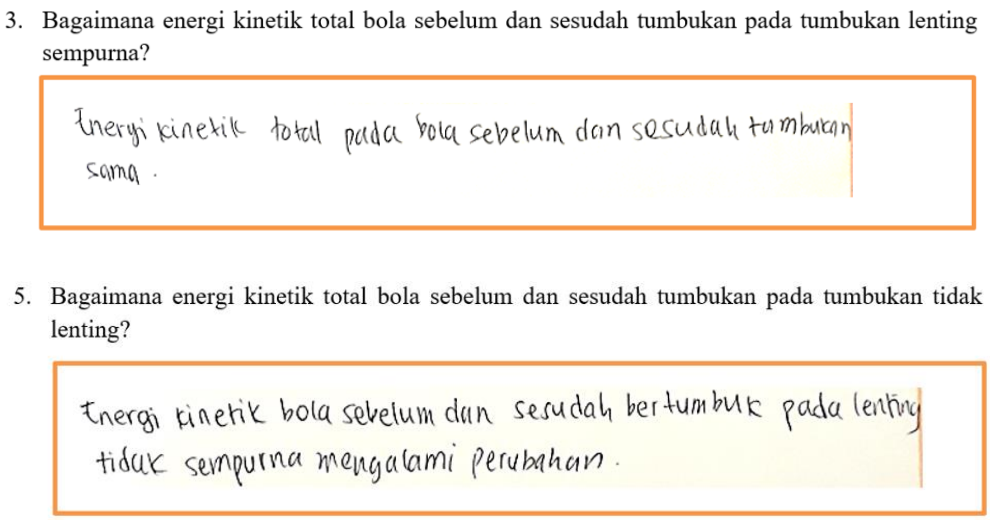
Momentum total sebelum dan sesudah tumbukan pd tumbukan lenting sempurna adlh SAMA

4. Bagaimana momentum total bola sebelum dan sesudah tumbukan pada tumbukan tidak lenting?

Momentum total sebelum dan sesudah tumbukan pd tumbukan tdk lenting adlh SAMA.

Figure 2. Students' answer on discussion questions about the total momentum before and after collision

Figure 2 shows students' answer for discussion questions on LKPD. Students were able to answer the questions according to experiment results. Therefore, students have already been able to solve the learning task. For example, students could answer the discussion questions for number two and number four from analyzed the experiment results that is "How is the total momentum of the ball before and after the collision on the elastic collision?" Students' answer was correct which is "total momentum before and after collision in elastic collision did not change. For the question number four which is "How is the total momentum of the ball before and after the collision on the inelastic collision?" Students' answer was "total momentum before and after collision in inelastic collision did not change"


3. Bagaimana energi kinetik total bola sebelum dan sesudah tumbukan pada tumbukan lenting sempurna?

Energi kinetik total pada bola sebelum dan sesudah tumbukan sama.

5. Bagaimana energi kinetik total bola sebelum dan sesudah tumbukan pada tumbukan tidak lenting?

Energi kinetik bola sebelum dan sesudah bertumbuk pada lenting tidak sempurna mengalami perubahan.

Figure 3. Students' answer on discussions questions about total kinetic energy before and after collision

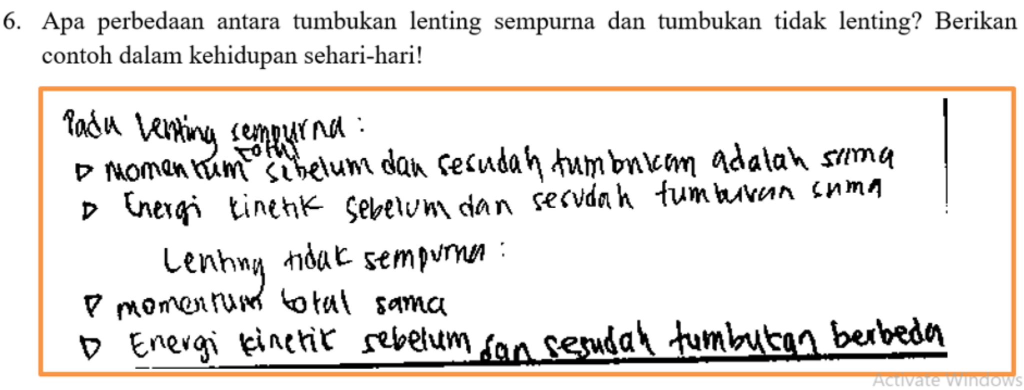


Figure 4. Students' answer on discussion questions about differences between elastic and inelastic collision

Students also were able identify the differences in total kinetic energy before and after collisions on elastic and inelastic collision (figure 3). Other than that, students have already been able to identify the differences between elastic and inelastic collision from the experiment data and discussion section (figure 4). Students have been able to complete the tasks with the scaffold (assistance/guidance/help) from the teacher. However, this assistance did not necessarily result in achieving a depth understanding of the concepts. The reseacher found that the scaffolding approach assisted by PhET simulation could be apply as a teaching strategy by teacher to increase students' activities. Communication and collaboration between students and between students and teacher increased. Students became more active in seeking knowledge. Students also have been able to complete the learning task.

3.2 Students' learning independence

The results of analysis for students' learning independence is presented in table 6 and table 7.

Table 6. Students' learning independence based on category

Category	Total students	Percentage
Good	19 orang	70,3 %
Good enough	8 orang	20,6%

Table 7. Students' learning independence based on each aspects

Aspect	Score (from total score 78)
Self-confidence	65
Responsibility	71
Initiative	70
Discipline	53

Table 6 shows that the learning independence of students were in good enough and good category. It shows that learning with the scaffolding approach assisted by PhET simulation is effective to improve students learning independence. If we see on aspects of students' learning independence (table 7), which is responsibility, initiative, and self-confidence have scored higher than the discipline aspect. This is because the teacher asked the students to complete and to present their learning tasks (LPKD) so that students were trained to be responsible for completing their tasks. Indicator of initiative aspect is students asked about the material which has not understood. Students were not being commanded by the teacher when asked the questions. Indicators for self-confidence are students were dare to express an idea and students were dare to ask or answer questions. In learning activities, some students asked for help during the discussion. Students asked the teacher when they did not understand during working on LKPD. The teacher also provide encourage questions to interest students at the beginning of learning. Therefore, students tried to answer the questions so students have demonstrated the initiative aspect. Score for discipline was the lowest score in all aspects. This aspect assessed through students who collected their task on time. This low value may be due to the teacher do not explicitly asked students to complete the learning task on time. When students told to present the results of the discussion, many students have not completed the task on time.

Scaffolding has been recognized as an effective learning strategy. Scaffolding learning could support learning in classroom [14] such as students' learning independence in the domain of science education [32]. The scaffolding approach assisted technological device functions as assistance to students' learning independence [33]. In spite of that, scaffolding could improve students' learning activities [12]. This learning approach provides interaction, collaboration, and communication to students. Therefore, scaffolding promoted students'activities or participation in class.

On the other hand, this study has also indicated the importance and necessity of embedding media in learning. Computer technology as a learning media have impacts on students and learning. Computer technology also provide opportunities for interaction, collaboration, and allowed student to engage communication [34]. Computer technology based simulation in learning could improve collaborative learning and students' learning experiences [21],[35]. Simulation became more effective if it utilize as a learning supplement or support [27]. PhET simulation helped students visual representations of physics concepts that cannot be directly observed [36]. As a learning media, PhET simulation provide media for inaccessible physics phenomena [37].

Although there was no significance difference on students' conceptual understanding in our research, learning oriented computer technology (simulation) integrate with scaffolding shows interesting features. First, the scaffolding and simulation are appropriate with the curriculum and 21st century learning. It provides interaction, collaboration, and communication to students. The second, students become more active and show interest in learning with scaffolding approach and simulation based learning (computer technology based learning). The participation of students improve in learning.

4. Conclusion

This paper has presented the effect of scaffolding approach assisted by PhET simulation on students' conceptual understanding and students' learning independence in physics. The result shows that within high school, scaffolding approach assisted by PhET simulation can be used to improve students' learning independence. Besides, students' activites were increased during the learning. Students became more active in seeking knowledge and interaction among students were also increased. Scaffolding approach with PhET simulation provides communication and collaboration activities. The scaffolding and simulation are appropriate with the Indonesian curriculum and 21st century learning.

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