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The Effect of Scaffolding Approach Assisted by PhET Simulation on the Achievement of Science Process Skills in Physics

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The Effect of Scaffolding Approach Assisted by PhET Simulation on the Achievement of Science Process Skills in Physics

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Abstract. This paper studies the effect of scaffolding approach assisted by PhET simulation on the achievement of science process skills in physics. This paper used pre-experimental design with a one-shot case study. The sample of this study was students of class XI MIPA MAN 1 Yogyakarta. The sample consisted of 2 classes with the total of 57 students from the whole 3 classes selected by purposive sampling technique. The scaffolding approach in this paper consists of three levels, those are environmental provision, reviewing and restructuring, and developing conceptual thinking. The data was collected through observation of science process skills by using a checklist sheet. Aspects of science process skills which was observed included observing, formulating hypotheses, conducting experiments, interpreting, concluding, and communicating. The data analysis used descriptive analysis, calculation of the percentage of achievement of each aspect of science process skills, and calculation of the percentage of categories of achievement of science process skills. The results of the study show that the scaffolding approach assisted by the PhET simulation has a very good effect in physics learning for the achievement of the science process skills in physics.

Keywords: PhET simulation; Scaffolding approach; Science process skills.

1. Introduction

The purpose of physics learning is to guide students to acquire basic knowledge that can be used to predict and explain a various natural phenomenon. Physics contains many concepts and principles that are commonly abstract. Therefore, a student is expected to have an ability to identify and interpret concepts and principles in studying physics. This ability is very useful especially when students are faced with certain physics problems and are asked to solve them. Students are required to be able to apply scientific methods as a step in solving problems [1]. The application of the scientific method in seeking knowledge needs the basic skill which is called science process skills [2]. Process skills should be mastered by students in order to be able to understand science [3]. The implementation of learning using science process skills is carried out through lab activity and affects the improvement of learning outcomes and the ability of creative thinking [4].

There are some previous studies that showed the level of the students' science process skills in Yogyakarta, Indonesia. The students' science process skills in one of the Senior High Schools in Yogyakarta are still in the range of 30.67%. The teacher has not expanded the students' science process skills in lab activities [5]. In line with this, the science process skills of high school students in several schools in Sleman Regency, Yogyakarta are in the range of 40% to 60%. Therefore, the special attention is needed from the teacher, especially in interpreting graphics skills and formulating conclusions [6]. At the elementary level, scores of students' science process skills in life aspect in Yogyakarta, Bantul, and Kulon Progo are still low, even there are some students who get a zero score [7].

It is necessary to have a physics learning innovation that is not only oriented to cognitive aspect but also emphasizes the scientific process skills aspect. Students can have the opportunity to achieve science process skills if the setting of the learning environment is designed appropriately [8]. One of the learning approaches that can be used is scaffolding approach. *Scaffolding* means providing a lot of support for children during the initial stages. The support is further reduced and the child is asked to assume greater responsibility when he is able to learn independently [9]. The context of learning with the *scaffolding* approach refers to the concept of teacher assistance which is given to students in constructing knowledge in the early stages. The assistance is increasingly reduced until students are finally able to understand physical concepts independently [9], [10]. Teacher's assistance and guidance through the experimental activities can significantly improve the physics learning outcomes and science process skills in terms of initial physics abilities [11]. According to Aini, *et al*. that the higher the students' scaffolding towards physics lessons, the higher students' learning outcomes [12]. Students who have high scaffolding in physics tend to be more active in learning activities in the classroom. Those students tend to have a high curiosity, for example, trying to find problem solving through experiments or discussions [12]. Abdul-Majeed and Muhammad stated that the application of scaffolding can also help students' understanding and facilitate students in working with peers or in group activities [13].

Referring to the nature of the learning approach, the scaffolding approach includes student's organization, the position of teachers and students, and the acquisition of skills in learning. According to Anghileri, the implementation of scaffolding in classroom learning is divided into three levels, namely: environmental provision level; level explaining, reviewing, restructuring; and level developing conceptual thinking. At the environmental provision level, the teacher designs the learning before interacting with students. The teacher forms a discussion group to solve a particular problem. At the explaining, reviewing, restructuring level, there is a direct interaction between the teacher and students regarding the issues discussed. During the explaining, the teacher manages and controls the structured conversations to explain the next steps which are planned. Explaining activities can be replaced by reviewing and restructuring. Reviewing relates to interactions where the teacher focuses students' attention on aspects related to the material through everyday experience. At the time of reviewing, students have been involved with the assignment. There are five types of interactions in reviewing activities, namely, looking, touching, and verbalizing; prompting and probing; interpreting students' actions and talk; parallel modelling; students explaining and justifying. Restructuring involves interactions such as the presentation of context by the teacher to help students recognize something based on experience. The experience presented is still closely related to the abstract problems faced. There are five types of interactions in restructuring activities, namely, provision of meaningful contexts to abstract situations, simplifying the problem, rephrasing students' talk, and negotiating meaning. Developing conceptual thinking level provides the opportunities for teachers and students to express their understanding together. The teacher encourages students to develop their ideas. Interactions at this level include developing representational tools, making connections, and generating conceptual discourse [10].

Innovation in physics learning is also needed as an effort to face the challenge in the 21st century. Physics learning must be able to keep it up to date with today's conditions which are increasingly competitive and higher achievement standards. One of the challenges of 21st century learning is the mastery and utilization of information and communication technology as a learning media [14]. Integration of technology in conceptual learning such as applications on tablet PCs can enhance student's performance in both basic physics concepts and advanced physics concepts [15]. Technology can facilitate self-learning, enable mentoring among peers, differentiate formative instruction and assessment, and improve students' involvement [16]. The implementation of the scaffolding approach in learning activities can be combined with the use of technology as part of 21st century learning. Albab proved that e-scaffolding learning which integrates scaffolding and technology can increase student's performance in completing academic tasks. E-scaffolding can also guide students to remember the basic concepts more complex and interesting [17].

There are various forms of technology-based learning media, one of them is a computer simulation. Simulation becomes a valid virtual experiment, so it can support to achieve a meaningful understanding [18]. Imitation of real-world along with its dynamic process in simulation facilitates users in accessing scientific illustration [19]. Computer simulation has proven to be a useful tool for learning physics, biology, chemistry, and earth science, especially when combined with other learning experiences. Virtual simulations integrated in scientific approach can significantly improve science process skills [20]. The research conducted by Saputra, *et al*. reveals about computer simulations such as PhET which complement KIT media as learning tools are declared feasible, practical, and effective. The PhET and KIT can be used as a media in natural science learning to sharpen the students' science process skills [21].

The PhET simulations were developed to support mathematics and science learning. The PhET simulations can support the development of process skills, affective goals, and content learning in an easy, free, and flexible way [22]. According to Rutten, *et al*. that the use of PhET simulations as an alternative to pre-laboratory activity can provide efficiency in learning. Students get a deeper understanding of the skills and tasks that must be done when practicing in a real laboratory [23]. The PhET simulations have included the Translation Utility which is useful for translating the native PhET language (English) into various languages [24]. Indonesian is one of the 57 types of language choices available, so it can ease teachers and students.

Based on the above description, it can be interesting to integrate PhET simulations in the scaffolding approach. So, this study aimed to know the effect of scaffolding approach assisted by PhET simulation on the achievement of the science process skills (SPS) in physics. The implementation of the scaffolding approach in this study includes the assistance of PhET simulation which is downloaded from https://phet.colorado.edu. The PhET simulation was used to explain the concept of refraction to students. This paper focuses science process skills on aspects of observing, formulating hypotheses, conducting experiments, interpreting and analyzing data, concluding, and communicating.

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 paper used pre-experimental design with a one-shot case study. The sample of this study was the students of class XI MIPA MAN 1 Yogyakarta. The sample consisted of 2 classes with a total of 57 students from the 3 classes selected by purposive sampling technique. This study was conducted from April 10 to May 7, 2018, at MAN 1 Yogyakarta. Research design is shown in Table 1.

Table 1. Research design

X[a]	O[b]

[a] learning with scaffolding approach assisted by PhET simulation.
[b] observation of science process skills.

The material used in learning activities was light refraction. The learning process was conducted in classrooms at the level of scaffolding environmental provisions to the level of reviewing. Furthermore, a plan-parallel glass experiment was done in the laboratory using student worksheet (LKPD) guidelines at the level of scaffolding reviewing to the level of developing conceptual thinking. The PhET simulation used to explain the concept of refraction to the students that occur at the reviewing level. The PhET simulation on this paper was downloaded from https://phet.colorado.edu [25]. An example of content of the PhET simulation in the form of an illustration of refraction in Snell's Law is shown in Figure 1.

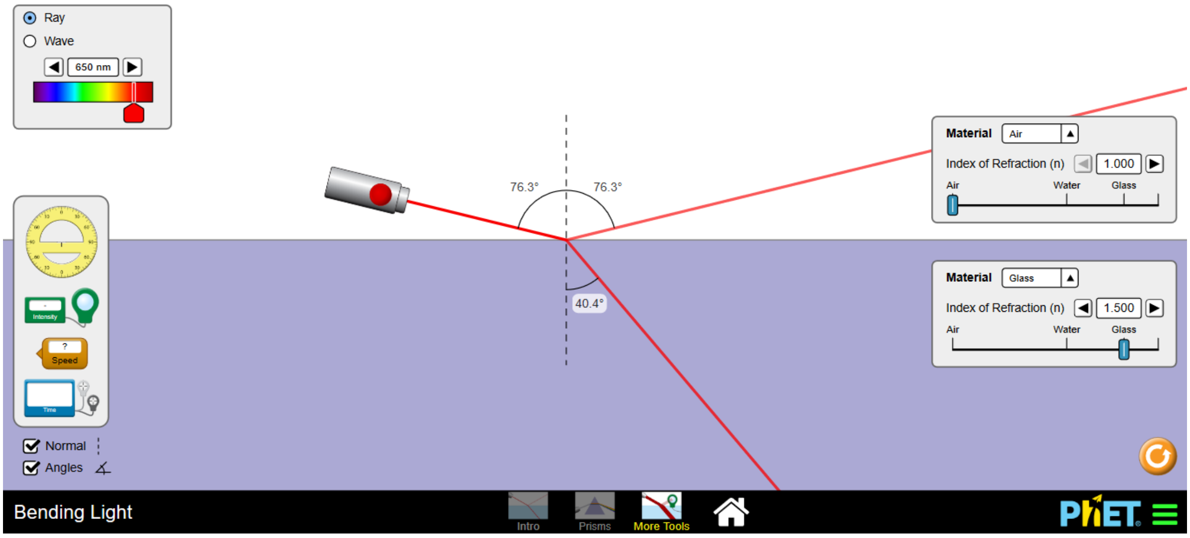

Figure 1. An example of display of PhET simulation on Snell's Law

Each level of the scaffolding approach in this study was given details by including the interactions that occur in the learning activities. The levels and interactions of scaffolding occupy positions that were adjusted to the 5M stages in the scientific approach that must be implemented in the 2013 curriculum learning. Table 2 presents the levels of scaffolding and the types of interactions, teacher's assistance activities and the integration of the PhET simulation in them, and aspects of science process skills that were trained or achieved.

Table 2. Matrix of scaffolding integration in the 5M scientific approach and its relationship to the aspects of science process skills

The Step of 5M learning	Level of Scaffolding	Type of Interaction	Scaffolding activities by the Teacher	Aspects of Science Process Skills that were trained/achieved
Observing	Level 1 Environmental provision	Orientation, Motivation, Apperception, Giving Reference	Providing guidance in operating PhET. Showing the phenomenon of straws looks broken in a glass of water and asking questions about it as motivation and apperception. Directing students to prepare plan-parallel glass experiment tools and materials.	Observing
Observing and asking	Level 2 Reviewing	Looking, Touching, and Verbalizing	Showing PhET simulation. Explaining Snell's Law about refraction based on the PhET simulation. Giving students the opportunity to operate PhET simulation about the phenomenon of refraction to deepen understanding. Giving students the opportunity to ask about the concept of refraction. Providing students the opportunities to clarify the solutions of questions that have been done by other students on the board.	Observing, communicating
		Prompting and Probing Interpreting Student's Actions and Talk	Answering students' questions by giving questions that lead to solutions. Concluding and clarifying the students' answers.	Formulating a hypothesis Concluding
		Parallel Modelling	Giving examples of problems and its solutions.	Analyzing
Collect information / experiments		Student Explaining and Justifying	Providing opportunities for students to discuss and actively participate in their groups in conducting plan-parallel glass experiments. Guiding and ensuring students do the steps of experiment correctly according to LKPD.	Observing, formulating a hypothesis, conducting an experiment
	Level 2 Restructuring	Provision of meaningful context to abstract situation	Assisting students by presenting context related to topics that students ask when having difficulties.	Interpreting
		Simplifying the Problem	Providing a simple analogy related to the lab activity when students really cannot solve the problem.	Interpreting
		Re-phrasing Students' Talk	Revealing and highlighting the results of lab activities, and revealing the statement of Snell's Law as a basis for students to check the suitability of lab activity results data.	Interpreting
		Negotiating Meaning	Agreeing (with students) on how data should be obtained from plan-parallel glass experiment.	Interpreting
Associating / Processing information	Level 3 Developing conceptual thinking	Developing Representational Tools	Supporting students to develop thinking in analyzing and interpreting lab activity result.	Analyzing and interpreting
		Making Connections	Directing to students so that they can relate lab activity conclusion to the phenomenon shown during apperception through structured questions.	Concluding
Communicating		Generating Conceptual Discourse	Giving students the opportunity to present the results of the discussion in front of the class. Giving students the opportunity to conclude the material that has been learned. Justifying students' conclusions. Confirming students' questions when shown the PhET simulation.	Concluding and communicating

Data was collected through observation of science process skills in physics based on lab activity that refers to the experimental steps in LKPD. The research instrument used was a checklist sheet, in which there was a table contained aspects of science process skills. Aspects of science process skills observed included observing, formulating hypotheses, conducting experiments, interpreting, concluding, and communicating. Each aspect consists of indicators in the form of statements that represent these aspects. The observer gave a check mark (√) in the indicator column that was fulfilled by each student of the lab work activity.

Some of the indicators of each aspect were also observed based on the results of student discussions that were expressed in write in the LKPD. Students discussed based on the help of discussion questions included by LKPD as shown in Table 3.

Table 3. Discussion question and the aspects of science process skills that were achieved

Discussion Question	Aspects of Science Process Skills that were achieved
Write a hypothesis (tentative answer) about the illustration presented in step 1 of experiment based on the material you have learned!	Formulating a hypothesis
What phenomena have you observed from the experiment steps number 4, 5, and 6?	Observing
What is the relationship between the experimental data you have obtained?	Analyzing and interpreting
What is the average refractive index of the plan-parallel glass you have obtained from the experiment?	Analyzing and interpreting
What are your conclusions about Snell's Law based on the experiment you have done? Explain in your own words!	Concluding
Based on the conclusions you have obtained from the experiment, why did the straws look bent in water? Explain it and relate your answers to the PhET simulation you have learned!	Concluding

Student discussions that were used to observe the indicators of conducting an experiment and communicating aspect were represented by their results of the experiment written by them in LKPD.

Data were analyzed using descriptive analysis to present data on science process skills in physics. The result of descriptive analysis of science process skills in physics that were presented included mean, standard error, standard deviation, minimum value, and maximum value. The calculation of descriptive statistics used percentage data of the achievement of the science process skills of each student that were converted into decimal. Achievement for each aspect was calculated based on the percentage of the number of students who fulfilled the indicators in each aspect compared to the total of students who became the sample of the study. These results were used to calculate the average achievement of science process skills in physics as shown in equation (1).

$$\text{Achievement of each aspect} = \frac{\text{number of students fulfilled the indicators in each aspect}}{\text{total of students became the sample of the study}} \quad (1)$$

In addition, the percentage of categories was calculated based on the comparison of the number of students who fulfilled each category of achievement of science process skills with the total number of students. The category used refers to Purwanto [26]. Table 4 presents the categories of science process skills.

Table 4. Categories of science process skills.

Percentage Score (%)	Category
86-100	Very good
76-85	Good
66-75	Sufficient
55-65	Bad
≤ 54	Very Bad

3. Results and Discussion

This study implemented a scaffolding approach assisted by a PhET simulation in learning to know its effect on the achievement of science process skills. The data in this study is students' science process skills obtained from observation. The descriptive analysis gave results summarized in Table 5.

Table 5. Result of Descriptive Statistics of Science Process Skills Score.

Measure of central tendency	Score
N	57.00
Minimum	61.00
Maksimum	94.00
Mean	86.88
Standard Error	1.060
Standar Deviation	8.002

Scaffolding approach and PhET simulation in this study can provide a meaningful learning experience which is shown by a mean score of science process skills in physics, that is 86.88. Scaffolding allows a child to have a good understanding of physical concepts. Scaffolding provides support to students during the initial stages of learning in constructing their knowledge, which is increasingly reduced until the students are finally able to understand physical concepts independently [27]. Definitely, this will have a good effect on their science process skills. The PhET as one of computer simulations can provide a more meaningful and understandable way for students in learning science concepts [28]. The students can obtain a suitable visual explanation of the refraction phenomenon that is modeled by the PhET simulation. It has an impact on better students' conceptual understanding after learning light refraction through PhET simulation [28]. In addition, computer simulations are proper to teach various scientific process skills include visualizing, classifying, solving problem, interpreting data, and designing experiment [19]. This is because PhET simulations, especially in physics, can illustrate phenomena in daily life specifically. The PhET 's assistance in supporting science learning by providing interactive and accessible simulations allows the development of science process skills [22]. This finding suggests that scaffolding approach assisted by PhET simulation can be used in physics learning to achieve science process skills.

Furthermore, the results were given more detail by calculating the percentage of categories based on the number of students who reach the category. Figure 2 presents the percentage of categories of achievement of science process skills.

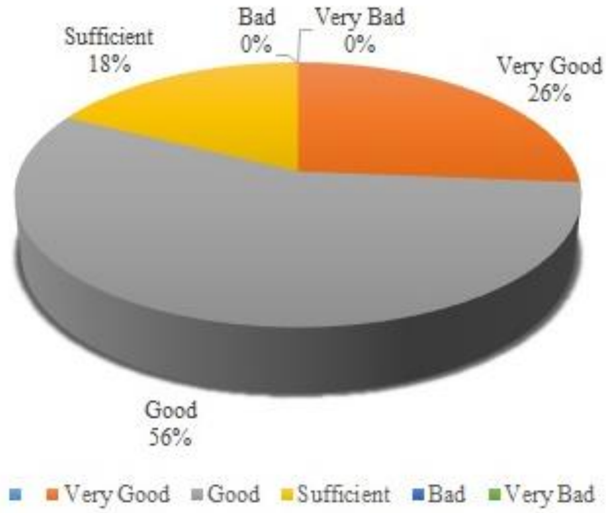

Figure 2. Percentage of categories of achievement of science process skills.

The achievement of science process skills is quite satisfying overall. The minimal science process skills are in the sufficient category. The teacher's support in this scaffolding approach contributes well to science process skills in physics. The PhET simulation's support which also implies scaffolding in it, can make learning effective and bring students on gaining knowledge. Especially in physics learning, a PhET simulation that is integrated in an effective scaffolding approach helps students achieve science process skills well [11], [19], [29]. It means integration of the scaffolding approach and PhET simulation is an appropriate learning environment, because learning environment designed appropriately can give students the opportunity to achieve science process skills [8]. In addition, someone who has high scaffolding of physics will tend to be more active during learning and have high curiosity. So, he/she will try to prove his/her curiosity through experiment [12]. Therefore, once again, scaffolding has a good effect on students' science process skills.

Most of students have science process skills in good categories after learning. In line with Siahaan, the use of computer simulations can improve students' science process skills in the medium category gradually [30]. This can be understood, at the beginning of the learning, students are still adapting to the scaffolding approach assisted by PhET simulation. Remembering the learning in this study was carried out for two meetings, definitely, the students needed time to adjust to new learning approach and media during that time.

There were students in sufficient categories as much as 18%. There were several aspects of science process skills that were not fulfilled by students with sufficient categories. One of the indicators is observing the measuring instrument scale with the correct direction of view in the observing aspect. This is reasonable because not all students had the opportunity to observe the measuring instrument scale, because of the limited time that required them to share tasks in groups. Furthermore, in the conducting an experiment aspect, they were careless in writing symbols, information, and variables in the worksheet. It also contributes to students with sufficient categories. Some students also still had difficulty in writing down the relationship of experimental data and their explanations descriptively in the interpreting aspects. The skill of writing the relationship of experimental data is no longer a basic skill, but it is included in integrated skills [27]. Therefore, it can be understood that this skill has a high level of difficulty.

The indicator of the concluding aspect that is not fulfilled by some students is linking the experiment with Snell's first Law. Some of these students also did not pay attention to the goals of the experiment, so not all experimental objectives were related to the conclusions they wrote. This aspect occupies the lowest percentage compared to other aspects of science process skills as presented in Figure 3.

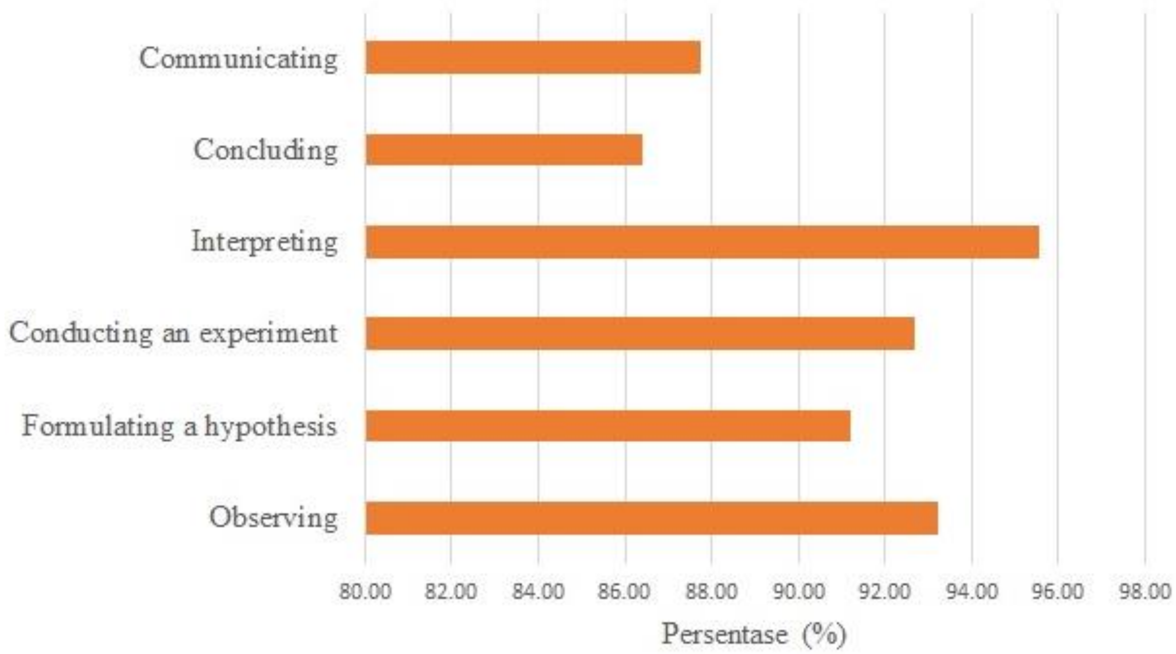

Figure 3. Achievement of science process skills in every aspect.

Another finding is the students who had inferior concluding aspects have not been able to make conclusions that can be used to explain other similar phenomenon. Other similar phenomenon in this context are apperception. Meanwhile, in the communicating aspect, the students have not understood the relationship between the PhET simulation and the experiments they did. It is seen from Figure 3, this aspect occupies the second lowest percentage after the concluding aspect. It can be understood that these students still cannot work independently when doing lab activity, even though, they were given assistance in the previous stage. This can happen to students who have not reached their zone of proximal development (ZPD). The assistance in scaffolding can work well when students are exactly at the point of readiness to receive certain information or tasks [9], [31]. So, more help is needed to guide until the students can achieve science process skills with their own abilities. This may be conducted but in its implementation, a more adequate time allocation is needed. In addition, time constraints were also the reason for students who could not verbalize the results of the experiment or convey their responses to the other groups.

The percentages of every aspect of science process skills shown in Figure 3 generate an average achievement of science process skills in physics of 91.14%. It can be said that all aspects of the science process skills are in the very good category. This means, overall the scaffolding approach assisted by PhET simulation has a very good effect in physics learning for the achievement of students' science process skills. The result is consistent with the research findings about e-scaffolding concept, that is the scaffolding activities actualized in online learning. E-scaffolding enables visual media presentation such as pictures and video, so it can improve students' reasoning [17]. The PhET simulation as one of visual media, which is integrated in scaffolding approach, can provide an overview of physical concepts which are quite abstract if it is only described descriptively. Students are also trained in remembering basic concepts that can be used to solve problems, which has a good effect on their achievement of science process skills.

4. Conclusion

Results of this study show that the scaffolding approach assisted by the PhET simulation has a very good effect in physics learning for the achievement of student science process skills in physics. These findings suggest that PhET simulation can be integrated in scaffolding approach in physics learning in order to achieve science process skills. For further research, it is recommended to test the effectiveness of the scaffolding approach assisted by PhET simulation on the improvement of science process skills through at least two lab activity meetings.

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