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Enhancing Students' Critical Thinking Skills through Physics Education Technology Simulation Assisted of Scaffolding Approach

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Abstract: This study aims to improve students critical thinking skills through Physics Education Technology Simulation assisted of Scaffolding approach. The study used the single pretest posttest group model (One Group Pretest Posttest) in one study class. Statistical test using paired sample t-test. The results of increased critical thinking skills were obtained based on percentage pretest and posttest results with descriptive analysis through criteria of critical thinking skills. Based on the result of t-test, the value of significance is 0.00, which is less than α (0.05) which means there is improvement of critical thinking skills through Physics Education Technology Simulation assisted of Scaffolding approach. The percentage of pretest value of 71% with good category and the percentage of Post-test score of 82% with very good category.

Keywords: Scaffolding approach; PhET simulation; Critical thinking skills

1. Introduction

Learning is the teacher's programmed activities in instructional design to make students learn actively which emphasizes the provision of learning resources [1]. Learning is an activity that must produce learning and teaching processes. Planning several activities oriented towards students so that learning occurs in students [2]. Physics is the science that is the basis for other science, such as astronomy, biology, chemistry, and geology. The beauty of physics lies in the simplicity of fundamental physical theories and in the way in which few fundamental concepts, equations, and assumptions can change and develop our view of the world around us [3]. Physics learning is an effort to teach students about physics from the aspects of theory, principles, concepts, laws, and equations through various strategies, methods, and approaches to achieve the planned goals. Programmed learning activities are carried out to increase student activity through the provision of learning resources.

Physics learning with today's technology cannot be separated due to the demands of the times. IT- based physics learning can encourage students' active involvement and the results show a significant increase in physics learning, because it requires innovative learning in implementing IT-based learning [4]. Science education especially in physics learning is able to build students' thinking ability [5]. Thinking ability is one of the life skills that you want to achieve in the 21st century. Some of the life skills demanded in the 21st chapter include communication, collaboration, critical thinking, and creativity and innovation. Through technology, of course some 21st century skills will be achieved. One of the abilities demanded is the ability to think critically. Efforts to improve



critical thinking skills are carried out through the application of appropriate and consistent learning models [6].

Students' thinking ability is one of the problems in the world of education in Indonesia, especially the ability to think critically. The Global Creativity Index (GCI) data in 2015 ranked Indonesia at 115th out of 139, meaning that Indonesia was in the lowest rank compared to other countries. The survey conducted by Martin Prosperity Institute assessed the creativity index of a country based on three indicators, namely technology, talent and tolerance. In this study, critical thinking skills will be improved through a Scaffolding approach assisted by PhET simulations.

Based on observations at XI MIA 3 MAN 1 of Yogyakarta City that learning using the PhET simulation assisted scaffolding approach has not been implemented in schools. The implementation of the PhET simulation uses learning with a learning model based on the 2013 curriculum. Learning with Scaffolding is one of the lessons that can improve critical thinking skills. The term Scaffolding is used in constructivism theory [7]. Scaffolding is a form of giving support and guidance gradually by people who are trained to students during the learning process [8].

Learning scaffolding by giving concept understanding can improve cognitive abilities [9]. Scaffolding approach that involves the activeness of students improves problem-solving skills [10]. The purpose of providing scaffolding in learning is to provide support and motivation for student learning so that students are able to think at a higher level, in this case the ability to think critically [11]. In addition, the scaffolding approach involves giving concepts from the teacher to students and students actively seeking information about the concepts given during the learning process [12]. Scaffolding approach is divided into 3 levels, namely provision environment; explaining, reviewing and restructuring, and developing conceptual thinking [13]. Based on the stages of learning with the Scaffolding approach, students gain learning experience. Learning gained based on learning experience can encourage critical thinking processes [14]. Learning experiences can be obtained through virtual lab assisted activities. The ability to think critically can be increased through scientific activities such as practical activities [15]. One of the virtual lab activities is carried out through the PhET Simulation technology. Learning by using PhET simulations can improve critical thinking skills [16], the use of technologies such as tablets or laptops that can produce virtual simulations and animations has the potential to support the exploration of scientific ideas [17].

The provision of PHET simulations can support the learning process, especially learning using scaffolding techniques. The provision of support and assistance in this case in the form of scaffolding techniques requires a medium both visual and audiovisual so as to deepen students' knowledge in learning competencies [18]. The provision of scaffolding can measure students' understanding in processing information and students' thinking skills [19].

Critical thinking demands a lot of effort to examine beliefs or assumptions based on supporting evidence and the subsequent conclusions they generate [20]. Critical thinking is reasonable and reflective thinking. Critical thinking ability focuses on deciding what to believe or do [5]. Critical thinking skills can be divided into 5 indicators, namely: (1) Elementary clarification, (2) Basic support, (3) Inference, (4) Advance clarification, and (5) Strategy and tactics [22]. These five indicators are reduced to sub indicators. Indicators and sub-indicators in this study are described in the following Table 1:

Table 1. Indicators of Critical Thinking Skills

No	Indicator of Critical Thinking Skills	Sub-indicator of Critical Thinking Skills
1	Elementary Clarification	Analyze arguments
2	Basic support	Observing and considering observations.
3	Inference	Making induction and considering the results of induction
4	Advance clarification	Define terms and consider definitions
5	Strategy and tactics	Decide an action

This study integrates a Scaffolding approach assisted by a PhET simulation with sub indicators of students' critical thinking abilities. The material provided regarding light refraction, Snellius I and II law, and the medium refractive index. The following is a table of learning relatedness using the Scaffolding approach assisted by a PhET simulation with students' critical thinking skills:

Table 2. Relationship between Treatment, Teaching Materials, and Variables

Scaffolding level	Sub indicator of Critical thinking skills	Light refraction material Learning	Activities	
			Teacher	Student
<i>Environment provision</i>	Observing and considering observations	Light refraction	Shows the PhET simulation related to the concept of refraction and asks students to formulate questions from the simulation	Observing the PhET simulation and formulating questions from the simulation
	Analyzing arguments	Snellius I and II Law	Explaining the material (explaining) and asking students to ask about the concepts that have been explained (reviewing)	Listening to the teacher's explanation and asking about the concepts that have been explained
<i>Developing conceptual thinking</i>	Analyzing arguments	Snellius I and II Law	Guiding students to answer questions and clarify student answers (restructuring)	try to answer questions from students who ask
	Making induction and considering the results of induction	Snellius I and II Law, absolute glass bias index planparalel	Allow students to do practicum, analyze data and discuss practical results	Results Analyze data and discuss practical results
	Decide an action			
	Defining terms and considering definitions.	Snellius I and II Law, absolute glass bias index planparalel	Invites students to present the results of practical	Presenting practical results
	Analyzing arguments	Snellius I and II Law, absolute glass bias index planparalel	Invite students to discuss with other groups then clarify or restate the results of the presentation and make conclusions	iscuss with other groups who give feedback or questions and make conclusions

PhET simulations in this study are related to Snellius's Law material about light refraction. The following is an animated image of PhET light from a medium to a medium with a medium density. Shown in Figure 1.

Departing from the background and problems above, research is needed that aims to improve students' critical thinking skills. Enhanced critical thinking skills are carried out through the application of learning with the Scaffolding approach assisted by PhET simulations.

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.

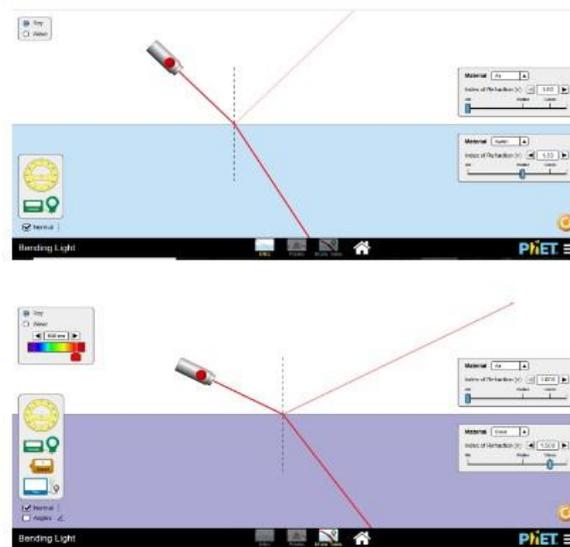


Figure 1. PhET simulation

2. Research Method

This study was an experimental study using the Single-group Pretest-Posttest method, where the research subjects were one group or one experimental class using the results of pretest and posttest. The study was conducted on April 26, 2018 at 07.15 to 08.15 and May 4, 2018 at 09.50 to 11:00 in class XI MIA 3 MAN 1 Yogyakarta. The research subjects were all students of class XI MIA1 MAN 1 Yogyakarta consisting of 30 students. The study used the Pretest&Post-test experimental method of one group of research subjects or the One Sample Group Pretest Post-test. The research design is explained as follows:

$$O_1 \times O_2 \quad (1)$$

Where O_1 as the pretest value before applying learning with the Scaffolding approach assisted by a PhET simulation, X as the treatment given is learning with a Scaffolding approach assisted by a PhET simulation, and O_2 as the post-test value before applying learning with a Scaffolding approach assisted by a PhET simulation. Data in the form of values with a scale of 1-3. The lowest value of each indicator is 2 and the highest value of each indicator is 6. The instrument in this study is a Student Worksheet (LKPD) based on the Scaffolding approach and test questions to measure critical thinking skills. The test is 10 questions, the indicator used is 5 indicators. So that each indicator is represented by 2 questions. Data collection techniques in this study are types of tests, namely the pretest and posttest questions. The pretest was given before the research and posttest questions were given after the study.

Data were analyzed descriptively and statistically. The results of the percentage of critical thinking indicators in the form of tables and graphs were analyzed descriptively based on critical thinking indicator criteria, while the test used to prove the improvement of critical thinking ability was paired sample t-test with normality test data using descriptive statistical tests. Hypothesis testing of the normality test was carried out at a significance level of $\alpha = 5\%$. Hypotheses testing used are:

H_0 : Data comes from populations that are normally distributed

H_a : Data does not come from a population that is normally distributed

If the significance is less than α (0.05) then H_0 is rejected, and if the significance is more than α (0.05) then H_0 is accepted.

The results of the data are the value of critical thinking skills in the form of numbers. The number is then converted into percentages and interpreted using criteria [23]. Critical thinking skills criteria are explained in the Table 3 below:

Table 3. Criteria for Critical Thinking Skills

NO	Percentage obtain	Criteria
1	81,25 % < x < 100 %	Very good
2	62,50 % < x < 81,25 %	Good
3	43,75 % ≤ x < 62,50 %	Sufficient
4	25,00 % ≤ x < 43,75 %	Less

$$\text{Percentage of critical thinking skills} = \frac{\text{score obtained}}{\text{maximum score}} \times 100 \% \quad (2)$$

The percentage results of each indicator were analyzed descriptively using the criteria table. Critical thinking ability improvement was analyzed using paired sample t-test. Testing of hypotheses and assumptions is carried out at a significance level of $\alpha = 5\%$. Hypotheses testing used are:

H_0 : Learning with the Scaffolding approach assisted by a PhET simulation cannot improve critical thinking skills.

H_a : Learning with a Scaffolding-assisted approach to PhET simulation can improve critical thinking skills.

Statistically written as follows:

$$H_0: \mu_1 > \mu_2$$

$$H_a: \mu_1 < \mu_2$$

If the significance is less than α (0.05) then H_0 is rejected, and if the significance is more than α (0.05) then H_0 is accepted.

3. Results and Discussion

Data resulting from critical thinking skills come from populations that are normally distributed. The results of the normality test for pretest and posttest data are explained as shown in Figures 2 & 3 below:

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	,187	30	,009	,935	30	,068

a. Lilliefors Significance Correction

Figure 2. Pretest Data Normality Test

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Post test	,157	30	,057	,959	30	,292

a. Lilliefors Significance Correction

Figure 3. Post-test Data Normality Test

Data from the pretest shows a significance value of 0.09 which is greater than α (0.05), so H_0 is accepted so that the data comes from a population that is normally distributed. The posttest data also shows a significance value of 0.057 which is greater than α (0.05) then H_0 is accepted so that the data comes from a population that is normally distributed. The results of critical thinking skills are measured using pretest and posttest questions. The critical thinking skills test results are shown in the following Table 4:

Table 4. Results of Critical Thinking Skills

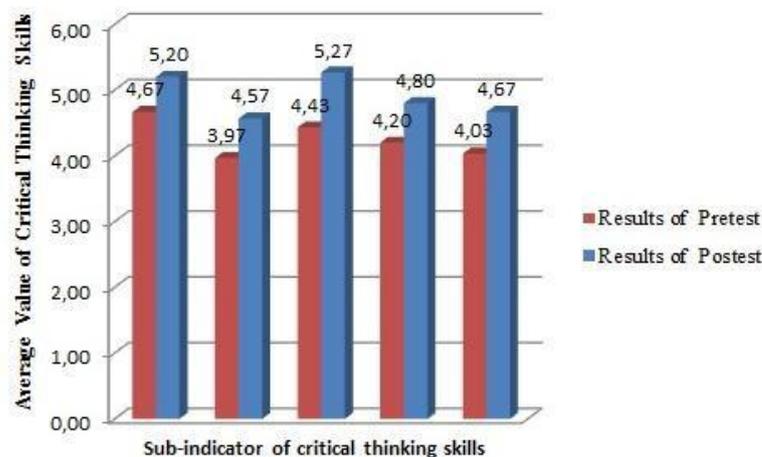
NO	Indicator of critical thinking skills	Sub-indicator of critical thinking skills	Value of the Average Pretest	Value of the Average Posttest
1	Elementary Clarification	Analyze arguments	4,67	5,20
2	Basic support	Observing and considering observations	3,97	4,57
3	Inference	Making induction and considering the results of induction	4,43	5,27
4	Advance clarification	Define terms and consider definitions	4,20	4,80
5	Strategy and tactics	Decide an action	4,03	4,67
Overall Average Value of Critical Thinking Skills			4,26	4,90

The results of conversion of critical thinking abilities in percentages are shown in the following Table 5 below:

Table 5. Percentage of Critical Thinking Skills

NO	Indicator of critical thinking skills	Sub-indicator of critical thinking skills	Value of the Average Pretest	Value of the Average Posttest
1	Elementary Clarification	Analyze arguments	78%	87%
2	Basic support	Observing and considering observations.	66%	76%
3	Inference	Making induction and considering the results of induction	74%	88%
4	Advance clarification	Define terms and consider definitions	70%	80%
5	Strategy and tactics	Decide an action	67%	78%
Overall Average Value of Critical Thinking Skills			71%	82%

The value of each indicator of critical thinking ability is not significantly different, but has increased when the pretest and posttest were carried out. Overall critical thinking skills also increased. The pretest value obtained was 4.26 with a percentage of 71% in the good category, experiencing an increase where the posttest value of 4.90 with a percentage of 82% was classified as very good. In this case there is an increase in criteria from good to very good. Indicator improvement results are also illustrated in the graph as shown Figure 4 below:

**Figure 4.** Graph of Increased Critical Thinking Skill

The indicator that experienced the biggest increase was the Inference indicator with the sub indicator making induction and considering the results of induction, while the indicator that experienced the smallest increase was the elementary clarification indicator with the sub indicator analyze arguments. Overall the use of a PhET simulation with a Scaffolding approach can improve

students' critical thinking skills. This is shown based on the results of paired sample *t*-test statistics in the Table 6:

Table 6. Paired Sample *t*-Test

		Paired Differences				t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest	-3.70	2.938	.536	-4.797	-2.603	-6.898	29	.000
Posttest	0							

Statistical results show a significance value (sig. 2 tailed) of 0.00 where the value is smaller than α (0.05). Because the significance value is smaller than α (0.05) then H_0 is rejected and H_a is accepted, i.e. the value of pretest is smaller than the value of posttest which indicates an increase in the results of students' critical thinking skills before and after being treated.

The Scaffolding approach is based on constructivism theory of learning, where student knowledge is obtained based on learning experience. Learning experience is obtained through cognitive processes. The cognitive process involves students' thinking skills. Through PhET simulation students are stimulated to think about the simulation shown. So that through this stage, students gain learning experience through thinking.

Learning that involves information technology can be supported by the provision of assistance so that learning can be effective, in this case using scaffolding techniques where the gradual provision of assistance from the provision of assistance then reduces the assistance so that students can process information independently [24].

Scaffolding assisted learning can improve the character of environmental care, critical thinking skills, and problem solving abilities [25]. Through the Scaffolding approach assisted by a PhET simulation, students are given motivation and guidance during the learning process. PhET simulation provide a stimulus so that students think critically about the phenomena that occur. Assisted learning PhET simulation can improve students' mastery of concepts and critical thinking skills [26].

The indicator that experienced the greatest increase was the Inference indicator with sub indicator making induction and considering the results of induction, this was because in LKPD students were asked to fill out the results table of the experiment and make generalizations from the results of the trial. This generalization is in the form of a relationship between the amount measured during the practicum. While the smallest indicator has increased is the elementary

clarification indicator with sub indicator analyzing arguments. At the time of the pretest, the average student was able to provide explanations and provide arguments regarding phenomena related to learning material, so that the results were not much different when holding a posttest question. The following is a table of experiments that used in this study as shown Figure 5 below:

D. Observation result

1. Make the right table in the column for observations and measurements!
Complete the data you get with the appropriate number of symbols and units!
2. Also calculate the large refractive index of parallel plan glass from each measurement that is done! Write down how the fair index is biased!

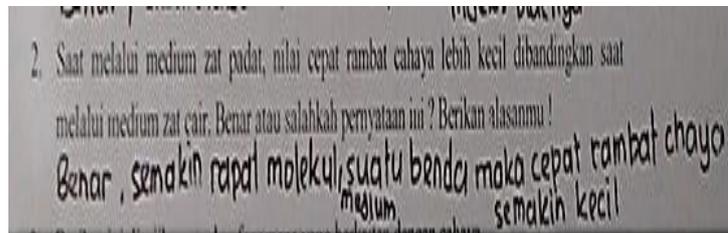
Experiment Results Table

Experiment	Ray angle comes (r_1)	Refractive beam angle (r_2)	Angle of i_1	Angle of i_2	Refractive index ($n_{\text{parallel glass plan}}$)
1	30°	30°	(measured)	(measured)	(calculated)
2	(measured)	(measured)	(calculated)
3	(measured)	(measured)	(calculated)

Figure 5. Data on Practical Observations

The following is an example of a question measuring the critical thinking skills used in this study:

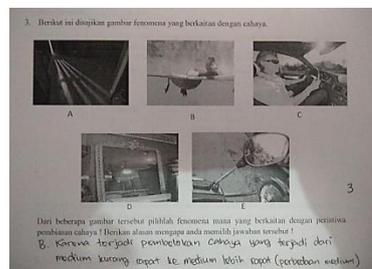
- a. Question to measure the ability to analyze argument



Comment:

Based on the answers, students get 3 points because they have explained the relationship between the density of the substance medium and the fast propagation value of the light traversed by the medium. The analysis is in accordance with the subject matter.

- b. Question for measuring the ability to observe and consider observations



Comment:

Based on the answers, students get 3 points because they have determined the phenomenon of refraction of light correctly and explain based on the subject matter.

c. Question to measure the ability to make induction and consider the results of induction

9. Dibawah ini merupakan tabel data hasil percobaan pembiasan (Sinar datang dari udara menuju ke bahan).

No	Bahan	Indeks Bias	Sudut Sinar Datang (i)	Sudut Sinar Bias (r)
1	Minyak goreng	1,47	30°	22°
2	Beni	2,42	30°	$13,45^\circ$
3	Air	1,33	30°	$22,5^\circ$

Berdasarkan hasil percobaan isilah tabel untuk sudut sinar bias yang dihasilkan dari masing-masing bahan tersebut. Bagaimana hubungan indeks bias suatu bahan dengan sudut sinar bias?

Sudut sinar bias = 30° ; $11,91^\circ$; $22,1^\circ$
 semakin besar indeks bias sud bendanya maka sudut sinar biasnya semakin mendekati garis normal.

3

Comment:

Based on the answers, students get 3 points because they have explained the relationship between the angle of light and the angle of refraction and the explanation is in accordance with the concept of learning.

d. Question for measuring ability to define terms and consider definitions

2. Berikut ini beberapa fenomena yang berkaitan dengan pembiasan cahaya.

Sinta berada di pinggir kolam renang dan melihat koin pada dasar kolam renang, saat ia ingin mengambil koin tersebut ternyata tidak seperti yang ia lihat, posisi koin lebih dalam dari penglihatan Sinta. Hal ini dikarenakan pembiasan cahaya oleh air sehingga koin terlihat lebih dangkal dari sebenarnya.

Berdasarkan fenomena tersebut, jelaskan bagaimana hukum Snellius II tentang pembiasan cahaya!

ketika sinar datang dari medium yang renggang menuju medium yang rapat maka cahaya dibiaskan mendekati garis normal.

3

Comment:

Based on the answers, students get a score of 3 because the answer is correct and is in accordance with the concept of Snellius Law.

e. Question to measure the ability to decide an action

7. Apa yang harus dilakukan untuk menentukan posisi ikan dalam air di kolam? Berikan penjelasanmu! dengan menggunakan rumus indeks bias.

2

Comment:

Based on the answers, students get a score of 2 because the answer is correct, but has not explained how the concept of the refractive index is used

4. Conclusion

Learning with the Scaffolding approach assisted by a PhET simulation can improve critical thinking skills, through learning stages with a Scaffolding approach able to improve the learning experience and students' thinking processes. Some learning models and learning approaches need to be integrated with technology, so learning can follow the development of the times and 21st century life skills can be achieved.

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