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Critical Thinking Skills and Physics Learning Outcomes in The 5E Learning Cycle Model with PhET Simulations

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ABSTRACT

This research aimed to examine: (1) the significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills; and (2) the significant effect of the 5E learning cycle model with PhET simulations on students' physics learning outcomes. The type of this research was true experimental with a post-test only control group design. The population of this research was students eleventh science grade of senior high school Balung in the even semester of the 2021/2022 academic year. The sample was determined using a simple random sampling method to obtain a selection of first science class as the experimental class and second science class as the control class. Data collection techniques include tests, interviews, documentation, and observation. Data analysis used is homogeneity test, normality test, and hypothesis test. The results of this research were: (1) there is a significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills; and (2) there is a significant effect of the 5E learning cycle model with PhET simulations on students' physics learning outcomes.

Keywords : *5E Learning Cycle, PhET simulations, critical thinking skills, physics learning outcomes*

I. INTRODUCTION

Learning is an interactive process between educators and students, with learning resources, learning strategies, teaching materials, and methods used in a learning environment [1]. Law number 20 of 2003 concerning the National Education System stated that learning is a process of student interaction with educators and learning resources in a learning environment. The learning process occurs throughout life and is carried out anywhere and anytime [2]. Physics subjects are related to human activities in the form of structured knowledge, ideas, and concepts about phenomena in the natural environment [3]. Physics does not only contain formulas and theories that must be memorized, but physics contains concepts that must be understood properly and correctly [4]. This means that physics learning is a learning activity that occurs because of the interaction of teachers with students effectively and efficiently in developing critical thinking about natural phenomena, a form of physics in the form of facts, concepts, principles, laws, and theories.

Twenty-first-century skills are needed for students who have 4C skills [5]. 4C skills include critical thinking, collaboration, creativity, and communication [6]. Critical thinking skills are an ability that can be accepted rationally, logically, and responsibly to believe so that the best conclusions can be drawn from the results of thinking [7]. Critical thinking skills are developed in the 21st century because critical thinking plays a vital role in education and social life. Through critical thinking skills, students can find the source of the problem and solutions to the issues they face [5]. Five aspects of critical thinking: elementary clarification, essential support, inference, advanced clarification, strategies, and tactics [8].

Based on data from the Ministry of Education and Culture website, in 2019, the average score for the Physics National Examination for senior high schools obtained the lowest average between biology and chemistry. Senior high school Balung is one of the senior high schools in Jember regency, with lower physics National Examination results compared to the National Examination results for other science subjects such as chemistry and biology [9]. Based on interviews with physics teachers and senior high school students, information was obtained that physics learning was more often carried out with lectures and practice questions. Practical activities are rarely carried out because the tools they have are limited. The tools they have are little causes the students' physics learning outcomes to be low. Expected learning outcomes are influenced by several factors, such as using learning models and facilities that support learning [10]. Bloom classified learning objectives into three domains, namely the cognitive, affective, and psychomotor domains [11]. Physics learning outcomes used in this study are in the mental (knowledge) realm. The cognitive part used is at the level of *remembering*, *understanding*, *applying*, and *analyzing*.

Presentation of physics material will attract students and achieve learning objectives if learning models and media are used in such a way [12]. An appropriate learning model and media are needed to achieve success in learning [13]. The selection of selected learning model and media must be suitable to be applied in a class. The learning cycle model is a student-centered learning model consisting of a series of activity stages arranged so students can achieve competence in learning [14]. The 5E learning cycle model is based on Piaget's constructivism learning theory, later developed by Robert Karplus. Learning with the learning cycle is done by linking the initial knowledge possessed by students with new knowledge obtained by students [3]. There are five phases in the 5E learning cycle model, namely: engagement, exploration, explanation, elaboration, and evaluation.

Critical thinking skills and students' learning outcomes can be improved through learning models. Kuba stated that students' thinking skills or reasoning power could be enhanced with the 5E learning cycle model because students are allowed to optimize their thinking skills [15]. Research conducted by Fuadi about The effect of the 5E learning cycle model on physics learning outcomes in senior high school Woha Bima students stated that there was a significant difference in students' physics learning outcomes between classes taught using the 5E learning cycle model and classes taught using conventional learning model [16].

Efforts that can be made to complement physics learning are utilizing information technology and computers. Computers can support the implementation of physics practicum, such as understanding concepts, collecting, processing, and presenting data. Computers can also run experiments in virtual form or commonly called Virtual Laboratory Model (VLM) [17]. Exciting and interactive learning media play an essential role in student learning [18]. Learning media is needed that can explain physics concepts to support physics learning outcomes. One media that can be used is PhET simulations [4]. PhET simulations aim to make the material presented to students readily accepted [18]. The initial appearance of PhET Simulations can be seen in Figure 1.

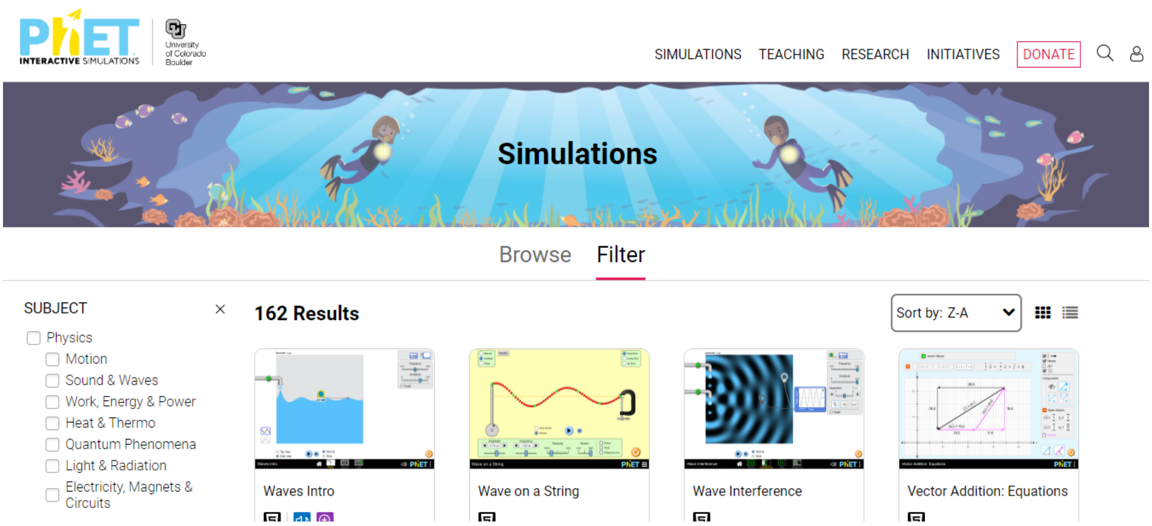

Fig. 1. *PhET simulations*
Source: https://phet.colorado.edu/in/simulations/filter

PhET simulations are interactive learning media and invite students to learn by exploring directly [4]. Through PhET simulations, abstract material can be explained easily so students can easily understand the material [19]. The results of Barokah research stated that students' critical thinking skills in the experimental class with the help of PhET simulations are more significant than in the control class using conventional learning [20]. Based on Sakdiah and Sasmita's research, the results of the hypothesis test state that learning with the help of PhET simulations has a significant effect on learning outcomes in the cognitive domain of students [21]. Research conducted by Saputra regarding the impact of using PhET (Physics Education Technology) media on physics learning outcomes stated that there was an increase in students' physics learning outcomes in the experimental class. The average value of student learning outcomes in the practical lesson is 80.57, while the average value in the control class is 75.60. The highest value in the experimental class is 96.00, while the highest value in the control class is 88.00 [4].

The 5E learning cycle model has several advantages. The advantages of the 5E learning cycle model are: 1) reducing the level of difficulty of the learning phase; 2) teachers can improve students' understanding of concepts and skills through experience; 3) encouraging students to connect past learning experiences with new ones; 4) provide opportunities for students to recognize new concepts owned, so that it can accommodate conceptual change; and 5) improve students' understanding and abilities, so that learning objectives can be achieved [22].

In addition to having advantages, the 5E learning cycle model also has deficiencies, there are: 1) requiring teachers to design and implement creative learning; 2) requires more time and energy so that the learning plans that are prepared can run effectively; 3) if the teacher does not understand the material and learning steps, the effectiveness of learning will be low; and 4) class management must be more planned and well-organized [23].

The deficiency of the 5E learning cycle model in this research can be minimized by using PhET simulations as learning media. Using exciting and interactive PhET simulations can make it easier for students to understand the studied material. PhET simulations can display information about processes and physics concepts that are pretty complete. In addition, PhET simulations can be accessed offline and online, wherever and whenever [24].

Based on the explanation of the problems of learning physics, research solutions can be done to overcome these problems. Therefore, this research discusses "Critical Thinking Skills and Physics Learning Outcomes in Learning the 5E Learning Cycle Model with PhET Simulations". This research aimed to examine: (1) the significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills; and (2) the significant effect of the 5E learning cycle model with PhET simulations on students' physics learning outcomes.

II. METHOD

The type of research used is true experimental with a post-test only control group design. This research was conducted at senior high school Balung on 05-19 April 2022 with a population of eleventh science grade for the academic year 2021/2022. There are two samples: first science class as the experimental class and second science class as the control class. The independent variable in this study is the 5E learning cycle model with PhET simulations, while the dependent variable is the critical thinking skills and students' physics learning outcomes. The instrument used is a test of critical thinking skills and a test of physics learning outcomes. The post-test consists of 5 questions arranged according to 5 aspects of critical thinking and 10 questions about physics learning outcomes arranged according to the cognitive domains C1 to C4. In addition, there is an observation sheet filled out by the observer when the learning activities are carried out in the experimental class.

Data analysis used was homogeneity test, normality test, and hypothesis testing with the help of the SPSS 25 program. A homogeneity test was used to determine whether the sample came from a population with the same variation. The homogeneity test used daily physics test scores on the previous material. The normality test was used to determine whether the data obtained were normally distributed. Then, the hypothesis was tested using the Independent Sample T-Test if the data were normally distributed. The Mann-Whitney U-Test was used if the data were not normally distributed.

The statistical hypothesis of the first research objective is H_0: there is no effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills, H_a: there is an effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills. The statistical hypothesis of the second research objective is H_0: there is no effect of the 5E learning cycle model with PhET simulations on students' physics learning outcomes, H_a: there is an effect of the 5E learning cycle model with PhET simulations on students' physics learning outcomes.

III. RESULTS AND DISCUSSION

Mathematical The experimental class used the 5E learning cycle model with PhET simulations, while the control class used learning usually applied in schools. The materials used are traveling waves and stationary waves. Three observers observed each meeting in the experimental class. The use of the 5E learning cycle learning model accompanied by PhET simulations is needed to improve critical thinking skills and students' physics learning outcomes. The 5E learning cycle learning model is constructivism and requires students to play an active role in learning. The use of PhET simulations media in learning physics can facilitate understanding of the material and overcome the limitations of the tools available in the laboratory.

The 5E learning cycle learning model consists of five phases, namely engagement, exploration, explanation, elaboration, and evaluation. In the engagement phase, the teacher displays a video related to the material, then students observe and respond to the video. In the exploration phase, students carry out experiments using PhET simulations in groups according to the available work steps. Furthermore, in the explanation phase, students analyzed the data from the PhET simulations experiments. The results of the experiment were presented and responded to by other groups in the elaboration phase. The last phase is evaluation, students conclude the results of the experiment. The teacher guides and directs students in each phase.

First science class is the experimental class and second science class is the control class. After learning, a post-test of critical thinking skills was conducted. Data on students' critical thinking skills were obtained from the post-test of the experimental class and the control class. The post-test was carried out after learning using the 5E learning cycle learning model accompanied by PhET simulations in the experimental class and learning as usual carried out by the teacher in the control class. The post-test questions are made according to aspects of critical thinking skills. There are five questions, each question is given a score on a scale of 1-4. The total score obtained is divided by the maximum score and multiplied by 100 to get the final score.The results of the post-test of critical thinking skills can be seen in Table 1.

Table 1. The results of the post-test of students' critical thinking skills

	Experimental Class	**Control Class**
Total students	36	36
The highest score	100	80
The lowest score	35	10
Average	81	55

Based on Table 1, the experimental class obtained a higher average than the control class. The average students' critical thinking skills in the experimental class were 81, while the control class was 55. The score of students' critical thinking skills can be seen in the large percentage for each aspect. This can be seen in Figure 1.

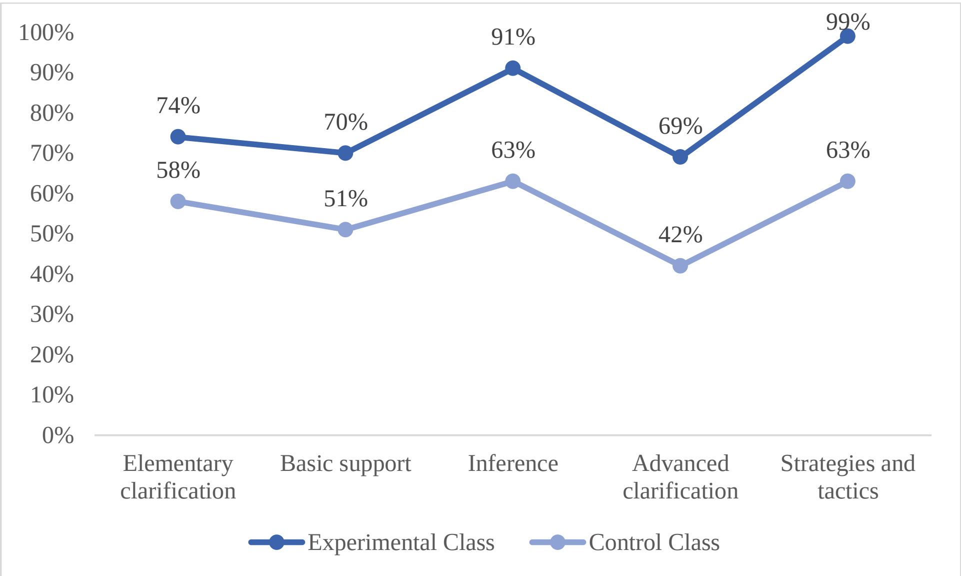

Fig. 2. Graph of post-test scores for critical thinking skills

Based on Figure 2, it can be seen that the average percentage of critical thinking skills in the experimental class is higher than in the control class. The average percentage of students' critical thinking skills in the experimental class was 81%, while in the control class, it was 55%. The experimental class got the highest score on the strategies and tactics aspect of 99% and the lowest score on the advanced clarification aspect of 69%. The control class got the highest score on the inference and strategies and tactics aspects of 63% and the lowest score on the advanced clarification aspect of 42%. Based on the category of critical thinking skills, the experimental class is included in the high category because the average value of 81 lies between 81,25 – 100. The control class is included in the low category because the average value of 55 lies between 43,75 – 62,25.

Post-test data on students' critical thinking skills were tested for normality using the One-Sample Kolmogorov-Smirnov Test of SPSS 25. The normality test is used to determine whether the data used is normally distributed or not. The normality test results of the One-Sample Kolmogorov-Smirnov Test can be seen in the Table 2.

Table 2. The results of the analysis of the normality test of critical thingking skills

One-Sample Kolmogorov-Smirnov Test			
		Experimetal Class	Control Class
Total students		36	36
Normal Parameters[a,b]	Mean	80.56	55.42
	Std. Deviation	13.721	17.170
Most Extreme Differences	Absolute	.183	.098
	Positive	.118	.093
	Negative	-.183	-.098
Test Statistic		.183	.098
Asymp. Sig. (2-tailed)		.004[c]	.200[c,d]
a. Test distribution is Normal.			
b. Calculated from data.			
c. Lilliefors Significance Correction.			
d. This is a lower bound of the true significance.			

There are two outputs that must be read in the normality test, namely the Test Statistics and Asymp values. Sig. (2-tailed). Based on the results of the One-Sample Kolmogorov-Smirnov Test, the experimental class obtained a Test Statistic score of 0.183 and Asymp. Sig. (2-tailed) 0.004, while the control class obtained a Test Statistic score of 0.098 and Asymp. Sig. (2-tailed) 0.200. The following is the basis for determining whether the data is normally distributed.

a. The data is normally distributed if the Sig. (2-tailed) $\geq$ 0.05, then the test used must then use a parametric statistical test.
b. The data is not normally distributed if the Sig. (2-tailed) < 0.05, then the test used must then use a non-parametric statistical test.

Value of Sig. (2-tailed) experimental class was smaller than 0.05 or can be written as 0,004 < 0,05. Value of Sig. (2-tailed) control class was higher than 0,05 or can be written as 0,200 $\geq$ 0,05. This means that the critical thinking skills data for the experimental class was not normally distributed, while the control class was normally distributed. Furthermore, a non-parametric statistical test was carried out, namely the Mann-Whitney U-Test. The results of the Mann-Whitney U-Test analysis can be seen in Table 3.

Table 3. The Results of The Mann-Whitney U-Test Analysis of Critical Thinking Skills Data

Test Statistics	
	Value
Mann-Whitney U	155.000
Wilcoxon W	821.000
Z	-5.574
Asymp. Sig. (2-tailed)	.000
a. Grouping Variable: Class	

Based on Table 3, the value of Sig. (p-value) critical thinking skills data was 0,000, or it can be written as 0,000 $\leq$ 0,05. It means that H_0 is rejected and H_a is accepted. It can be concluded that there is a significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills.

The difference between the experimental class and the control class is influenced by the 5E learning cycle model with PhET simulations applied in the experimental class. The control class applies the usual learning methods by physics teachers at senior high school Balung by using the lecture method and doing practice questions. All aspects of critical thinking skills are trained when learning in the experimental class using the 5E learning cycle model with PhET simulations. The elementary clarification aspect is trained in the engagement phase. The basic support aspect is trained in the exploration, explanation, and elaboration phases using PhET simulations. The inference aspect is introduced at the end of the phase, namely the evaluation phase. The advanced clarification aspect is trained in the explanation and elaboration phases when using PhET simulations. Strategies and tactics aspect are also trained when using PhET simulations, precisely in the phases, namely the exploration, explanation, and elaboration.

The results of this research are by Septiana, who stated that the 5E learning cycle model significantly affects critical thinking skills, so the experimental class average was 70,28, while the control class was 62,39 [25]. The other research by Handayanti stated that the use of PhET simulations media shows a significant difference in the value of critical thinking skills and physics learning outcomes between the experimental and control classes [26].

The second data in the form of students' physics learning outcomes were obtained from the post-test of the experimental class and the control class. The post-test was carried out after learning using the 5E learning cycle model with PhET simulations in the experimental class and learning as usual by the teacher in the control class. The post-test questions were made according to the cognitive domain, namely remembering, understanding, applying, and analyzing. In summary, the post-test results on physics learning outcomes can be seen in Table 4.

Table 4. The results of the post-test students' physics learning outcomes

	Experimental Class	Control Class
Total students	36	36
The highest score	100	50
The lowest score	15	05
Average	61	31

Based on Table 4, physics learning outcomes in the experimental class obtained the highest score was 100, and the lowest score was 15, while in the control class, the highest score was 50, and the lowest score was 05. The experimental class obtained a higher average than the control class. The average physics learning outcomes of students in the experimental class were 61, while the control class was 51.

Furthermore, the post-test data on students' physics learning outcomes were tested for normality. Post-test data on students' physics learning outcomes were tested for normality using the One-Sample Kolmogorov-Smirnov Test normality test with the help of SPSS 25. The normality test was used to determine whether the data used was normally distributed or not. The normality test results of the One-Sample Kolmogorov-Smirnov Test can be seen in the Table 5.

Table 5. The results of the analysis of the normality test of data on physics learning outcomes

One-Sample Kolmogorov-Smirnov Test

		Experimental Class	Control Class
Total students		36	36
Normal Parameters[a,b]	Mean	60.64	31.47
	Std. Deviation	21.453	12.277
Most Extreme Differences	Absolute	.099	.132
	Positive	.077	.088
	Negative	-.099	-.132
Test Statistic		.099	.132
Asymp. Sig. (2-tailed)		.200[c,d]	.118[c]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

There are two outputs that must be read in the normality test, namely the Test Statistics and Asymp values. Sig. (2-tailed). Based on the results of the One-Sample Kolmogorov-Smirnov Test, the experimental class obtained a Test Statistic score of 0.099 and Asymp. Sig. (2-tailed) 0.200, while the control class obtained a Test Statistic score of 0.132 and Asymp. Sig. (2-tailed) 0.118. The following is the basis for determining whether the data is normally distributed.

a. The data is normally distributed if the Sig. (2-tailed) ≥ 0.05, then the test used must then use a parametric statistical test.
b. The data is not normally distributed if the Sig. (2-tailed) < 0.05, then the test used must then use a non-parametric statistical test.

Based on Table 5, value of Sig. (2-tailed) data on physics learning outcomes of experimental class students was 0,200, and the value of Sig. (2-tailed) control class was 0,118. Value of Sig. (2-tailed) the experimental class was higher than 0,05 or can be written as 0,200 ≥ 0,05. Value of Sig. (2-tailed) the control class is higher than 0,05 or can be written as 0,118 ≥ 0,05. It means that the data on physics learning outcomes of experimental class and control class students were normally distributed. Based on these results, data analysis can be continued using the Independent Sample T-test. The Independent Sample T-test analysis results can be seen in Table 6.

Table 6. The results of the analysis of the independent sample t-test of physics learning outcomes data

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Value	Equal variances assumed	8.174	.006	7.080	70	.000	29.167	4.120	20.950	37.383
	Equal variances not assumed			7.080	55.703	.000	29.167	4.120	20.913	37.420

Based on Table 6, the value of Sig. (2-tailed) physics learning outcomes data was 0,000, or it can be written as 0,000 ≤ 0,05. It means that H_0 is rejected and H_a is accepted. It can be concluded that there is a significant effect of the 5E learning cycle model with PhET simulations on students' physics learning outcomes.

The difference between the experimental class and the control class is influenced by the 5E learning cycle model with PhET simulations applied in the experimental class. The control class applies the usual learning methods by physics teachers at senior high school Balung by using the lecture method and doing practice questions. Cognitive domains C1 to C4 are trained when learning in the experimental class using the 5E learning cycle model with PhET simulations. The cognitive domain of remembering is trained in the engagement and elaboration phases. The cognitive understanding domain is trained in the engagement, explanation, elaboration, and evaluation phases when using PhET simulations. The cognitive applying domain is introduced at the end of the phase, namely the exploration, explanation, and elaboration phases using PhET simulations. The cognitive domain of analyzing is trained in the exploration, explanation, elaboration, and evaluation phases when using PhET simulations.

The results of this research are by the research of Fuadi, who stated that there is a significant effect on students' physics learning outcomes using the 5E learning cycle model [16]. Ulumiyah stated that using PhET simulations on elasticity and Hooke's law effectively improved students' physics learning outcomes [27]. It is also supported by the research of Saputra which stated that PhET simulations media could improve physics learning outcomes. The average physics learning outcomes of the experimental class were 80,57, while the control class was 75,60 [4]. The use of PhET simulations in designing the practicum module studied by Aryani is effective in helping students explore physics material [28].

The results of interviews with physics teachers at senior high school Balung after the research showed that the 5E learning cycle learning model with PhET simulations in the experimental class was more effective than in the control class. It can be applied to other materials. The interviews with several experimental class students prove that learning using the 5E learning cycle model with PhET simulations is easier to understand and fun because it can do practical work through PhET simulations. Students can discuss, present, conduct experiments, and ask questions through this learning. Students play an active role during learning, for example, when a video is shown, students respond to each other and actively discuss when conducting experiments. Students conducting experiments using PhET simulations can practice critical thinking skills and understand physics through technology.

The implementation of learning in the experimental class is supported by the existence of an observation sheet filled in by the observer. Each meeting consists of three observers. In the first meeting, learning was carried out successively, namely 90.6%, 90.6%, and 89%. In the second meeting, learning was carried out successively, namely 96.9%, 90.6%, and 90.6%. Overall the average implementation of learning is 91% with all learning steps implemented.

There were obstacles in the implementation of learning using the 5E learning cycle model with PhET simulations. Constraints in this research are limited learning time and some students who are not present in learning due to other activities. The solution applied is to maximize the use of learning time and provide material in the form of files to students who are not present.

IV. CONCLUSION

Based on the results of the research and discussion, it can be concluded that (1) there is a significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills; and (2) there is a significant effect of 5E learning cycle model with PhET simulations on students' physics learning outcomes. It is evidenced by the results of hypothesis testing using the Mann-Whitney U-Test on critical thinking skills data and the Independent Sample T-Test on physics learning outcomes data. In addition, the observation of the implementation of learning using the 5E learning cycle model with PhET simulations is 91% with all the learning steps carried out. Therefore, the 5E learning cycle model with PhET simulations is expected to be an alternative to technology-based learning to improve the quality of education. The 5E learning cycle model with PhET simulations can be applied to other materials with a more planned design.

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