

# Application of e-handout based on PhET simulation to improve critical thinking skills and learning independence of high school students

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**Abstract.** This study aims to determine the application of e-handout with the help of PhET simulation model of problem-based learning integrated with LMS Edmodo to improve critical thinking skills and students' learning independence in class X of SMAN 1 Sleman on collision material and the law of conservation of momentum. This research is an experimental design study. The design of this study is one-group pretest-posttest design model. The method of data collection is using the results of the initial and final tests in both the experimental class and the questionnaire of learning independence. The results showed that students' critical thinking skills and independence of learning in both classes improved after using PhET-assisted e-handouts. Conclusion The application of e-handouts with the help of the PhET simulation model of problem-based learning can improve critical thinking skills and there is a difference in the learning independence.

**Keywords:** *e-handout, problem based-learning, PhET*

## 1. Introduction

In the 21<sup>st</sup> century learning, skills are needed to face the problems and challenges of globalization [1]. The solution to dealing with these problems is by applying learning that trains students to think in order to foster students' critical thinking skills [2]. Critical thinking skills are one of the needs of students to solve problems in everyday life [3]. However, the critical thinking ability of physics in high school students is still in the moderate category [4]. This is because of the students' initial perception of physics as a subject that is difficult to understand and not interesting [5], [6]. When working on physics problems students will find it difficult to understand questions and solve problems [7], [8] which results in students' critical thinking skills being low [7], [8].

The results of observations of learning in class X SMAN 1 Sleman showed learning activities do not actively involve students. The facilities provided such as LCD projectors are less utilized for learning. Only some students show active or positive attitudes towards learning. When allowed to conclude learning activities, only a few students who dare to convey conclusions. There were no students who took the initiative to conclude. This showed that the independence of learning physics students is still lacking [9].

The lack of learning independence of these students must be overcome by applying learning that can foster the enthusiasm and motivation of students in the hope that students' critical thinking abilities can



increase physics. One solution is to apply appropriate media and learning models. A learning model that can train students' thinking skills is Problem Based Learning (PBL) [10].

PBL can stimulate students to learn through real problems in everyday life and encourage understanding of scientific knowledge [11]. PBL is very relevant in this 21<sup>st</sup> century and is very suitable for the implementation of the 2013 curriculum where students are required to be more active as well as independent learning exercises [12]. In addition, the application of PBL can be supported by learning media that is compatible with technological developments and 21<sup>st</sup> century challenges, namely digital technology [13], [14].

Handouts usually contain material that is concise, concise but clear, which is able to encourage students to think systematically [15]. In this teaching material combined with electronic media in the form of e-handouts equipped with PBL-based student worksheet so students are required to be active in the learning process. This e-handout learning is assisted by the PhET simulation in student worksheet. In physics learning practicum in this school, learning will apply PBL models assisted by PhET simulations. PhET simulation includes interactive learning that can provide opportunities for students to learn the material at any time, can be repeated until understanding the concept, guiding to experience the learning process independently [16].

Students generally have computer/laptop facilities to access the PhET simulation program via the internet based on ICT [15]. PhET simulation is used as an implementation of 21<sup>st</sup> century learning. Students conduct experiments using a PhET simulation to prove and formulate the law of conservation of momentum.

Learning to utilize technology assistance in the form of Edmodo is expected to be able to improve ICT physics literacy in students. In addition to social networking media among its users, Edmodo also supports online learning processes [17]. Online social networking sites are perfect as communication tools to build knowledge based on social relations, communication, collaboration and sharing of tasks. Edmodo makes it easy for students and educators to communicate outside the classroom so that they are more independent in learning [18].

Learning by using media is expected students to be able to understand the material being taught well, students' critical thinking skills increase and students have a positive attitude towards learning physics especially the attitude of learning independence.

## 2. Research method

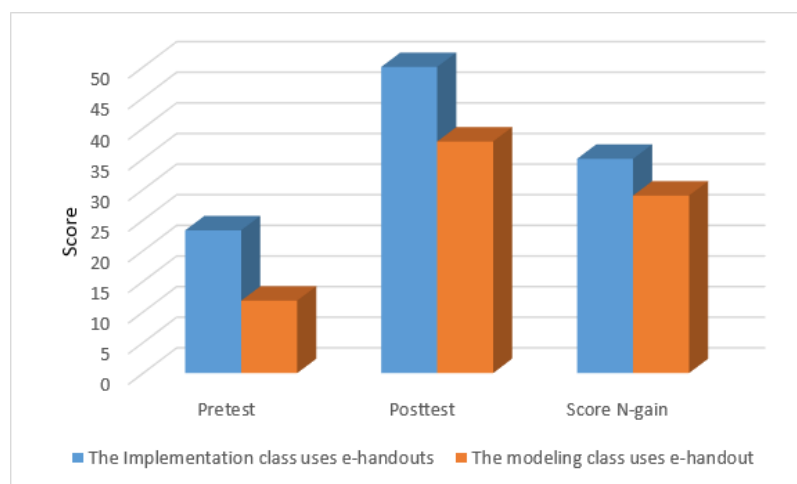
The method used in the study is the quasi experiment method with the design of "one group pretest-posttest design" which was carried out in class X SMAN 1 Sleman in the academic year 2018/2019. The subjects in the study were students of class X MIPA 1 or class modeling taught by researchers and X MIPA 3 or implementation classes taught by teachers. Each class consists of 30 people for the modeling and implementation class. Data collection is done by using the initial test and final test for critical thinking skills and questionnaires to determine the independence of the learning of students. Initial and final test results were analyzed to find out the N-gain of students' critical thinking skills. Comparison of the N-gain value of critical thinking between the modeling class and the implementation class was tested using a statistical difference test of two averages (t-test) through SPSS 20 software. Questionnaire items were given to the implementation class and the control class which aimed to determine the learning independence of students.

## 3. Results and Discussion

### 3.1. Description of students' critical thinking skills

Analysis of the results of applying the PhET simulation-based e-handout to improve critical thinking skills in the collision material and the law of conservation of momentum is done by comparing the normalized average gain values between the modeling class conducted by researchers with the implementation class conducted by the subject teacher. The comparison of the average value of the initial test, final test, and n-gain (in percent) between the modeling class and the implementation class

is shown in figure 1. The initial test and final test data in figure 1 showed the average score of the modeling class experienced an increase of 26.67%, while the implementation class increased by 26%. The average n-gain score for the modeling class was 0.35 included in the medium category, while the average n-gain score for the implementation class was 0.29 included in the low category.



**Figure 1.** Comparison of average scores and N-gain scores.

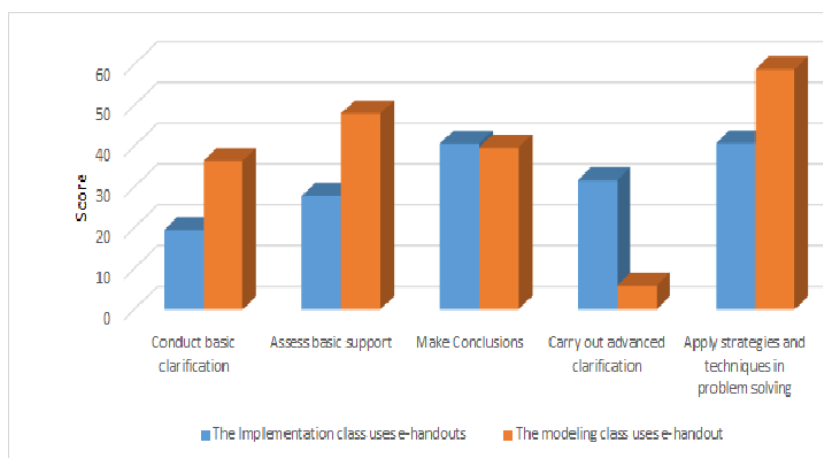
Analysis of the initial test results of students' critical thinking skills, it is known that the average score of the modeling class and implementation class is relatively low before the application of e-handout based on simulation the PhET. So it can be concluded that the two classes have relatively similar initial abilities. It is assumed that the instrument is to measure the students' initial ability in the modeling class and implementation material which have not been taught before.

After giving treatment to the two groups through the application of the same learning only different teachers, then given a final test to find out the improvement in students' critical thinking skills. Based on the results of data analysis, it is known that the average percentage of N-gain scores for modeling class is not satisfactory because the average value of n-gain is only 0.35 included in the medium category and implementation class obtains an n-gain value of 0.29 included in the low category. However, based on the data of the research results there is an increase in critical thinking skills seen from the average score of the initial test and final test of 26.67% for the modeling class and 26% for the implementation class.

Dissatisfaction with the average increase in students' critical thinking skills is thought to be due to the lack of trained thinking skills of students during the learning period so that it takes a continuous process to train students' thinking abilities to answer the ability challenges in the 21<sup>st</sup> Century.

Figure 2 showed the n-gain for each indicator of critical thinking for the indicator analyzing argument obtained n-gain scores for the modeling class of 0.19 the low category and implementation class of 0.36 the moderate category, the indicator assesses the credibility of the source for the modeling class of 0.28 the low category and implementation class is 0.48 the moderate category, indicator makes inductive conclusion for modeling class is 0.41 the medium category and for implementation class is 0.4 the medium category, indicator identifies assumption for modeling class of 0.32 in the medium category and in the implementation class of 0.06 in the low category, and the indicator of making decisions in action for the modeling class of 0.41 in the medium category and in the implementation class of 0.59 in the moderate category.

The data in the n-gain comparison diagram of each critical thinking indicator looks interesting, that is, in indicators 1 and 2 in modeling class it gets a low category, while in implementation class it gets a medium category, and in indicator 5 both classes both get a medium category. This is presumably because the characteristics of students differ and the influence of teacher differences in learning.



**Figure 2.** Comparison of the N-gain score for each indicator.

The results of the static analysis of the paired sample t-test test also showed that for modeling class an average of the results of the initial test of critical thinking skills was 23.33 and for the average results of the final test of critical thinking skills of 50.00. As for the implementation class, the average results of the initial tests of critical thinking skills were 11.83 and the average results of the final tests of critical thinking skills were 37.83.

The average value of the results of critical thinking skills in modeling class was obtained by initial test  $23.33 < \text{final test } 50.00$ . While the average value of critical thinking skills in the implementation class obtained an initial test of  $11.83 < \text{final test } 37.83$ , then it means descriptively there are differences in the average results of critical thinking skills between the initial test and the final test.

SPSS output table paired samples correlation test for modeling class obtained a correlation coefficient (correlation) of 0.613 with a significance value (Sig.) Of 0.000. Because of the value of sig.  $0.000 < \text{probability } 0.05$ , it can be said that there is a relationship between the initial test variable and the final test variable. Whereas for the implementation class a correlation coefficient of 0.526 was obtained with a significance value (Sig.) Of 0.003, because of the value of sig.  $0.003 < \text{probability } 0.05$ , it can be said that there is a relationship between the initial test variable with the final test variable.

Paired sample t-test, modeling class, and implementation output tables are known to be Sig. (2-tailed) is  $0.000 < 0.05$ , then  $H_0$  is rejected and  $H_a$  is accepted and the modelling class is  $t_{\text{count}} > t_{\text{table}}$  is  $10.449 > 2.045$  and implementation class is  $t_{\text{count}} > t_{\text{table}}$  is  $9.425 > 2.045$ . So it can be concluded that there is an average difference between the results of the critical thinking skills preliminary tests with final tests, which means that there is an influence of the use of e-handouts assisted by PhET simulations in improving students' critical thinking abilities for collision subject matter and the law of conservation of momentum in class X SMAN 1 Sleman.

### 3.2. Description of learning independence of students

The results of research conducted in both modelling and implementation classes found data in table 1. Table 1 show the percentage of indicators of learning independence for the modeling class and implementation class using e-handouts assisted by the PhET simulation Problem based learning model on the first indicator, namely the independence of others by 57% and 67% the category is good. The data can be concluded that both classes can learn independently. The desire of students to learn new things both class and outside the class independently using e-handouts. This can be caused because in the learning process, students who use the problem based learning model are invited to find and solve their own problems. So they can add new sciences that have not been taught by educators.

The problem based learning model that is more centered on students frees them more to find solutions to problems related to learning material. In his research [19], found that the average teenager spends about 500 hours a year studying. It was found that adolescents who became respondents completed as

many as 5 learning projects per year and more than 70% were done alone. This shows students tend to be open to learning new things.

**Table 1.** Percentage of indicators of learner learning independence in the modeling class and implementation class.

Aspects of Learning Independence	Modelling Class		Implementation Class	
	Percentage (%)	Category	Percentage (%)	Category
Dependence on others	57	Pretty good	67	Pretty good
Have trust	63	Pretty good	65	Pretty good
Behave discipline	57	Pretty good	58	Pretty good
Have a sense of responsibility	66	Pretty good	66	Pretty good
Behave based on initiative	53	Not good	66	Pretty good
Exercise self-control	59	Pretty good	70	Pretty good

Learning with the presentation session of the findings in class using the problem based learning model, each of which is 63% and 65% good enough category means that students have the confidence to display their findings. Indicators of discipline behavior between the two experimental classes were 57% and 58%. This indicates that most students already have self-awareness both in managing time and in learning.

The fourth indicator representing the receipt of information as a form of own responsibility shows that the percentage of classes using the problem based learning model of the two experimental classes is equal 66%. Self-Direct Learning (independence of learning) will cause students to increase the responsibility for their learning, be willing and able to learn with themselves and others, play a role in their progress and self-discipline [20]. As a result, the role of learning independence for students is very necessary.

Learning independence will have many competencies that can be achieved simultaneously in the education process [21]. Indicators of behaving initiative for both experimental classes obtained 53% and 66% of the categories are quite good. Learning independence will be flexible with any learning model that can enhance these characteristics.

The last indicator of self-control of the two classes gained 57% and 70%. The key aspects of learning independence in question are students learning according to their abilities with the time that is tailored and scheduled to their learning styles and the involvement of people around to support and optimize the success of students through the development and sharing of knowledge [22]. This resulted in the need for direction and involvement of educators in an effort to increase learning independence for each learning material.

Normality test using SPSS 20 program based on Shapiro-Wilk normality test outputs is known Sig value. The modeling class Sig. value 0.376 and the implementation Sig value 0.140. Because the value of Sig. for the two classes  $> 0.05$ , then as the basis for decision making in Shapiro-Wilk normality test, it can be concluded that the data of students' learning independence for modelling class and implementation class are normally distributed. Then the homogeneity test is performed and the F data table is 0.003. Based on the data above, it is known that the calculated F value of 6.881 so that  $F_{\text{count}} > F_{\text{table}}$ . It can be concluded that the learning independence score between modeling class and implementation class is not homogeneous.

The test continues with the independent sample test to test the hypothesis. Decisions based on Sig. Levene's test for equality of variances is  $0.04 < 0.05$  so it can be interpreted that the data variance between

modeling class and implementation is not homogeneous. So that the interpretation of the independent output table of the Sample Test is guided by the values in the equal variance not assumed table.

Based on the independent sample test output table in the equal variances assumed section, the Sig. (2-tailed) of  $0.007 < 0.05$ , it was concluded that  $H_0$  was rejected and  $H_a$  was accepted. Thus it can be concluded that there is a significant difference between the average results of students' learning independence in the modeling class and the implementation class.

#### 4. Conclusion

Based on the results of study and the discussion associated with the hypothesis in this study, it was concluded that: (1) there was an effect of the application of e-handout assisted by a PhET simulation model of problem based learning in improving the critical thinking skills of students of class X MIPA SMAN 1 Sleman (2) there were differences in the application of e-handout is assisted by the simulation of the PhET model problem based learning on the learning independence of students of class X MIPA SMAN 1 Sleman.

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