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Physics Learning Design of Faraday's Induction Law Material Using PhET Simulation

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ABSTRACT

The purpose of this research is to make a learning design on Faraday's Induction Law using a PhET Faraday's Electromagnetic Lab simulation and to investigate the effectiveness of the design on students' understanding. Descriptive research was used as the method of this research. The instruments of this research were the observation sheet on students' attitudes and learning activities, questionnaires, and cognitive evaluation test questions. There were 14 students of grade IX of a Junior High School in Salatiga as the respondents of this research. The data collected from the research instruments were then analyzed using the descriptive qualitative technique. Based on data analysis of the observation results of learning activities, students' attitudes, questionnaires, and cognitive evaluation test scores; the results showed that the learning design for Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab was effective to help students understand the Faraday's Induction Law.

ABSTRAK

Tujuan penelitian ini adalah untuk membuatan desain pembelajaran tentang Hukum Induksi Faraday menggunakan simulasi PhET "Faraday's Electromagnetic Lab" dan menyelidiki efektivitas desain tersebut terhadap pemahaman siswa telah dilakukan. Metode penelitian yang digunakan dalam penelitian ini adalah penelitian deskriptif. Adapun instrumen penelitian yang digunakan dalam penelitian ini, yaitu lembar observasi sikap siswa dan Kegiatan Belajar Mengajar (KBM), kuisioner serta soal tes evaluasi kognitif. Kuisioner dan soal tes evaluasi kognitif diberikan kepada 14 orang siswa kelas IX SMP Negeri di Salatiga sebagai responden dalam penelitian ini. Data-data yang telah dikumpulkan dari instrumen penelitian tadi kemudian dianalis menggunakan teknik analisa data deskriptif kualitatif. Berdasarkan analisa data hasil observasi KBM, observasi sikap siswa, kuesioner, dan nilai tes evaluasi kognitif siswa, diperoleh hasil bahwa desain pembelajaran tentang Hukum Induksi Faraday menggunakan simulasi PhET "Faraday's Electromagnetic Lab" ini efektif digunakan untuk membantu siswa dalam memahami materi Hukum Induksi Faraday.

Keywords: Faraday's Electromagnetic Induction; Physics Education Technology (PhET); Virtual Laboratory.

INTRODUCTION

Many students have difficulty in understanding the concept of physics involving abstract variables, such as the relationship between the induced current and magnetic field in the Faraday experiment. The proof of the theory cannot be seen directly by the naked eye; for example, the explanation of the movement of electrons, magnetic field, and direction of the induced current generated cannot be directly observed. Therefore, those phenomena cannot easily be understood by students (Thamrin, Sudarmi, & Noviandini, 2012). These difficulties caused students to need more time to understand the material of Faraday's Induction Law (McKagan et al., 2008). Also, teachers' explanation in the classroom is not adequate to make students understand a concept involving these abstract variables (Pujiyono, Sudjito, & Sudarmi, 2016) since they are invisible. As an answer to this issue, laboratory equipment used to explain Faraday's Induction Law material is very much needed (Warjanto, 2015). However, some schools have limited la-

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boratory equipment that forces teachers only to choose the lecture method to teach Faraday's Induction Law. As a result, the learning process is ineffective, and it makes students think that physics is a complicated and unpleasant subject.

Thus, effective learning media to support physics learning on abstract material or difficult material is needed. The use of learning media can be done by using simulation such as a virtual laboratory, a substitute for laboratory equipment in a real laboratory (Silva Jr., 2015). One simulation that can be used as complementary material from teaching media in the virtual laboratory is PhET (Physics Education Technology) (Hapsara, Sudjito, & Noviandini, 2016). PhET is a collection of interactive, fun, and research-based science simulations that can be accessed free of charge at https://PhET.colorado.edu/. The PhET developed by the University of Colorado seeks to visualize and map science concepts so that they can be easily understood by students in the science learning process (The PhET Team, 2011).

One of the simulations in PhET is the simulation of Faraday's Electromagnetic Lab. The PhET simulation of Faraday's Electromagnetic Lab can help students visualize the movement of electrons, magnetic fields, and the direction of the induced currents generated in Faraday's experiments.

This research aims to create a learning design about Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab and investigate the effectiveness of the design on students' understanding.

METHOD

Description research was used as the research method in this research by using the following research instruments.

1. The Learning Implementation Plan on Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab that was implemented for 14 students of grade IX of a State Junior High School in Salatiga.
2. The observation sheet was filled out by the observer during the learning activities taking place to record the learning process conducted by the teacher and to observe the attitude of students during the activities in the classroom.
3. Evaluation test questions were given to students at the end of learning to determine students' understanding of the subject of learning.
4. Questionnaire sheets were given to students to determine students' responses to learning using the PhET simulation of Faraday's Electromagnetic Lab.

All data from the results of observation sheets, questionnaires, and tests were collected and processed to determine the effectiveness of the learning design about Faraday's Induction Law.

All of the data that had been collected was analyzed using the qualitative-descriptive technique for data analysis. The criteria for success of this research are:

Observation Sheet of Learning Activities

The learning design of Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab is stated to be effective if ≥ 70% of the total number of students respond positively to the learning activities.

Student Attitude Observation Sheet

The learning design of Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab is stated to be effective if ≥70% of the total number of students get a value ≥70 on each attitude assessment item.

Test Score

The learning design of Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab is stated to be effective if ≥70% of the total number of students get ≥70 of the test score.

Questionnaire

The learning design of Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab is stated to be effective if ≥70% of the total number of students give a positive response to ≥70 statements in the questionnaire.

RESULTS AND DISCUSSION

Learning Activities

The researchers had created a learning design on Faraday's Induction Law in the form of a Learning Implementation Plan using the PhET simulation of Faraday's Electromagnetic Lab, which was implemented towards 14 students of grade IX of a State Junior High School in Salatiga in the learning activities. The features of the PhET of Faraday's Electromagnetic Lab simulation are compatible with the components of the electromagnetic induction practicum tools. The components of the electromagnetic induction practicum tools, such as magnets, coils of different turns, and ammeters to measure the induced current generated (Warjanto, 2015).

The learning design that was created consists of the following four learning activities:

Activity 1. Definition of Magnetic Field

In the first experiment, students were asked to observe the iron powder sprinkled on a paper in which a bar magnet was placed under the paper. Based on students' observations, 100% of students (14 students) gave their opinions that the iron powder was magnetized and formed a pattern of lines. Students were then informed that the lines formed by the iron powder were magnetic lines and the area where the magnetic object was located still influenced by the magnetic force called a magnetic field (Damli & Yavas, 2016).

In the second experiment, students were asked to observe the staples placed around a bar magnet sprinkled with iron powder. Based on observations, students answered that the staples inside the iron powder were pulled by the bar magnet, while the bar magnet did not pull the staples outside the iron powder. Students were then informed that the iron powder that formed a pattern of lines indicated the presence of a magnetic field (Elok, Widodo, Wasis, & Suhartanti, 2008). Therefore, students stated that the bar magnet could draw the staples that were placed inside the iron powder because the staples were inside the magnetic field. All students then concluded that a magnet could attract objects surrounding it because those objects are in the scope of a magnetic field. Therefore, they are influenced by magnetic attraction.

Activity 2. Magnitude and Direction of the Magnetic Field

The experiment that uses Faraday's Electromagnetic Lab simulation in PhET virtual laboratory was carried out to investigate the magnitude and direction of the magnetic field. The simulation was done with the position of the field gauge on two lines, four lines, and six lines of the bar magnet (around the magnetic pole of the bar and between the north pole and the south pole of the magnetic bar) as shown in Figure 1. The magnitude of the observed magnetic field strength was written on tables of observation. Based on observations, all students considered that the magnetic field strength at a distance of two lines > magnetic field strength at a distance of four lines > magnetic field strength at a distance of six lines and the direction of the magnetic field that was from the north pole to the south pole. The students' answers showed that the PhET simulation helps them visualize an abstract event to be a more concrete event (Thamrin, Sudarmi, & Noviandini, 2012).

All students finally concluded that the

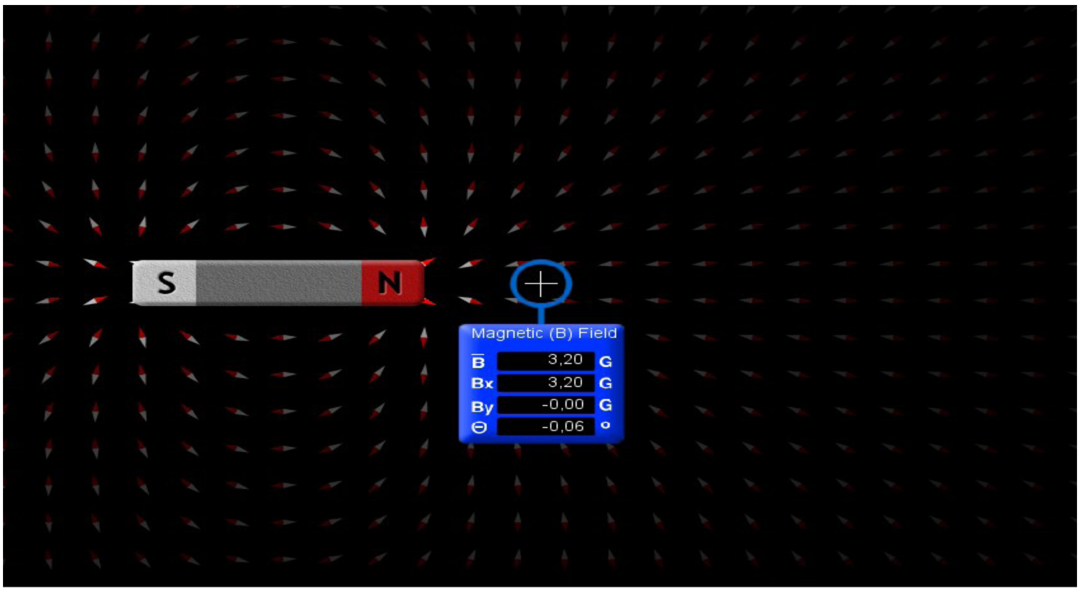


Figure 1. Magnetic field strength when the gauge of the magnetic field is at a distance of 2 lines from the bar magnet

magnetic field strength in the area near the bar magnet was more significant than the magnetic field strength in the area far from the bar magnet, and the direction of the magnetic field was from the north pole to the south pole (Damli & Yavas, 2016).

Students could see the direction of the magnetic field by looking at the north pole of a small compass that also draws a magnetic field line. At the north pole of the bar magnet, the direction of the north pole of the small compass comes from the north pole of the bar magnet. While at the south pole of the bar magnet, the direction of the north pole of the small compass goes to the south pole of the bar magnet. Therefore, students were able to answer that the direction of the magnetic field is from the north pole to the south pole (Puspita & Rohima, 2009).

After experimenting, students were asked to explain again about the magnitude and direction of the magnetic field and 57% of students (eight students) could explain them while 43% of students (six students) did not give their responds.

Activity 3. Faraday's Induction Law

Students experimented by moving a bar magnet inside a coil, resting inside a coil, and exiting a coil with Faraday's Law simulation in the PhET virtual laboratory, as shown in Figure 2. Based on observations, all students answered that when a bar magnet is moved (in and out) of the coil, the needle position of voltmeter moves, the light is on, and the magnetic flux changes. In contrast, when the bar magnet is left in the coil, the voltmeter needle does not move, the light is not on, and the magnetic flux does change.

Students were then informed that the currents caused by changes in magnetic flux in the coil were induced currents (Elok, Widodo, Wasis, & Suhartanti, 2008). All students then concluded that the lamp in the circuit light up when the bar magnet is moved (in and out) of the coil due to changes in the magnetic flux that results in an induced ggl which then generates an electric current that lights the lamp (Yunita & Ilyas, 2019). However, when the magnet is stationary in the coil, the lamp does not turn on because there are no changes in the magnetic flux in the coil (Puspita & Rohima, 2009). After experimenting, students were asked to explain again about the magnitude and direction of the magnetic field, and 57% of all students (8 students) could explain to them while 43% of all students (6 students) did not give the response.

Activity 4 – Factors Affecting the Induction Flow Strength

In Activity 4, students provided a hypothesis that factors influencing the induced current strength are: the change in magnetic flux, the speed of magnetic motion, the electric voltage, and the quality of lamp on the coil.

Experiment 4a – Effect of Magnetic Motion Speed on the Induced Current Strength

Students determined that the speed of magnetic motion as an independent variable.

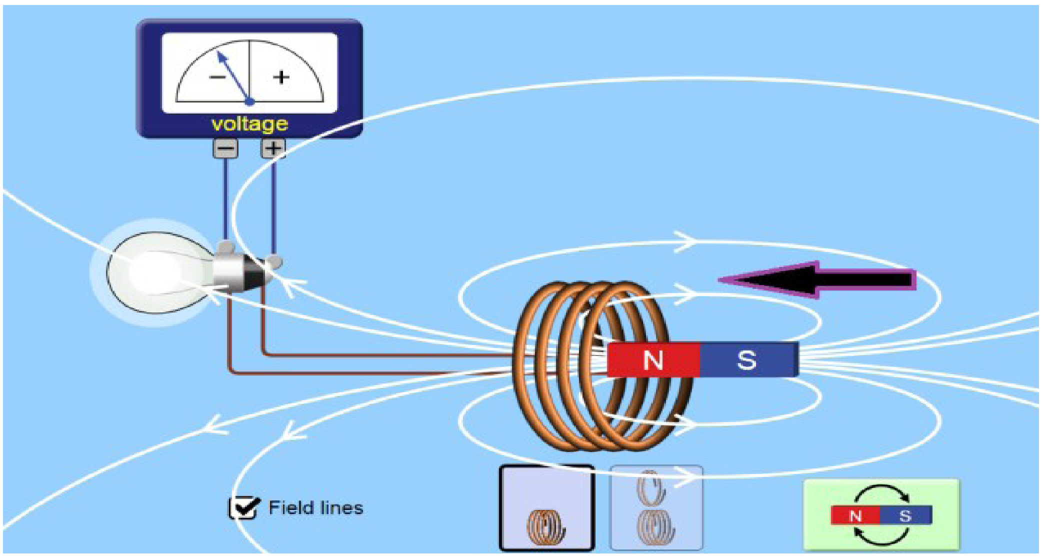


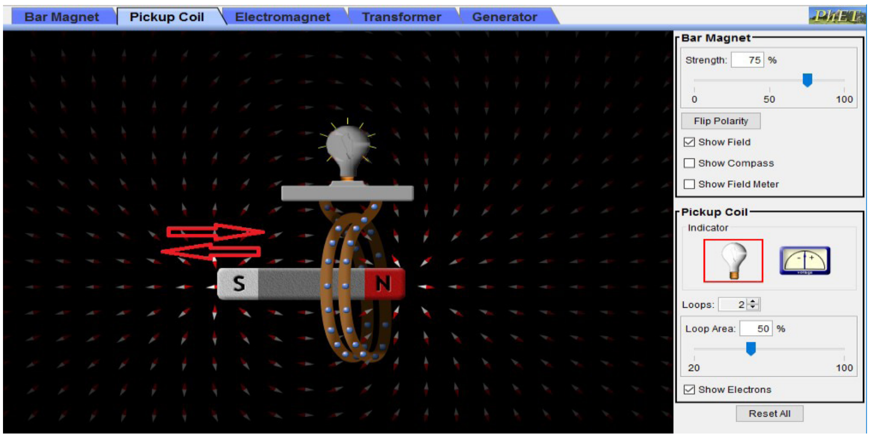
Figure 2. The positions of the voltmeter needle, light of lamp, and the amount of magnetic flux in the coil as the bar magnet is moved into the coil

While the number of coils and magnetic field strength as control variables, and the induced current strength as a bound variable through an experiment that uses a PhET simulation. As shown in Figure 3, which the observation tables were filled out by students, which the number of coils used was two turns, the magnetic field strength was 75%. The bar magnet was moved (in and out) of the coil in slow motion and then in fast motion.

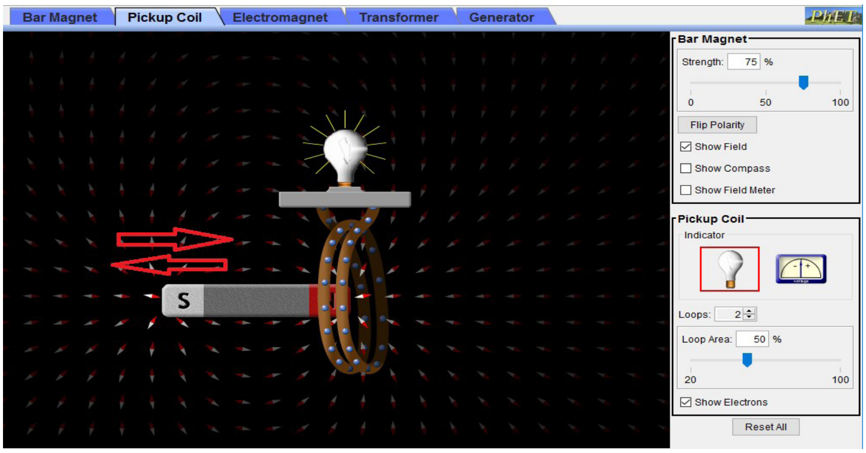
Based on the observation, the students answered that the lamp is on when a bar magnet is moved in and out of the coil with a slow and fast magnetic motion speed. All students then concluded that the light of the lamp would be brighter when a bar magnet is moved. It was quicker than the light of the lamp when a bar magnet is moved slowly in and out of the coil.

Experiment 4b – Effect of Total Turns on the Induced Current Strength

Students conducted experiments as shown in Figure 4 by determining the number of turns as the independent variable, the speed of magnetic motion and magnetic field strength as control variables, and the induced current strength as the dependent variable. Students then filled out the observation table where the speed of motion of the magnet was made fixed, the magnetic field strength was at 75%, and the bar magnet was moved (in and out) of the coil with the number of turnings: one turn, two turns, and three turns. Based on observations, students answered that when the bar magnet is moved in and out of the coil with one turn, two turns, three turns, the light is on. All students then concluded that the lamp is brighter when a bar magnet is moved with three turns than the bright of the lamp when a bar magnet is moved in and out of the coil with two turns. Moreover, the lamp is brighter when a bar magnet is moved in and out of the coil with two turns than the bright of the lamp when a bar magnet is moved in and out of the coil with one turn (Yunita & Ilyas, 2019).

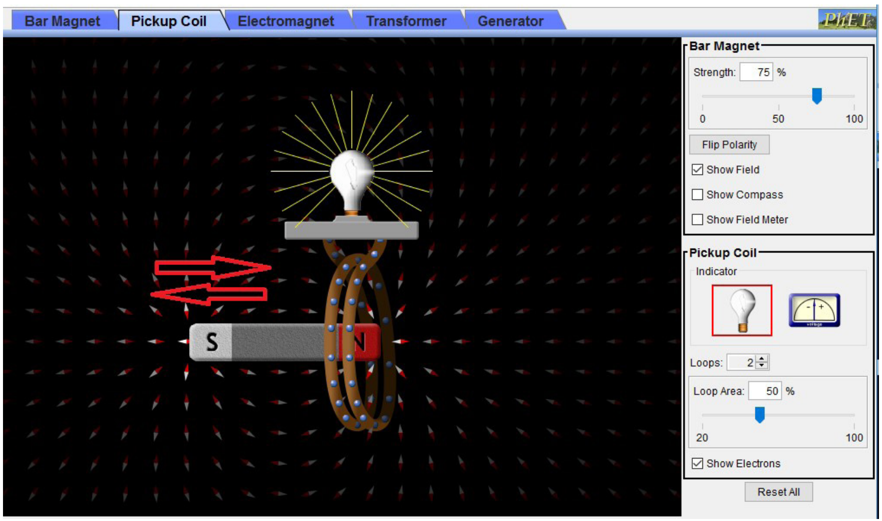


(a)

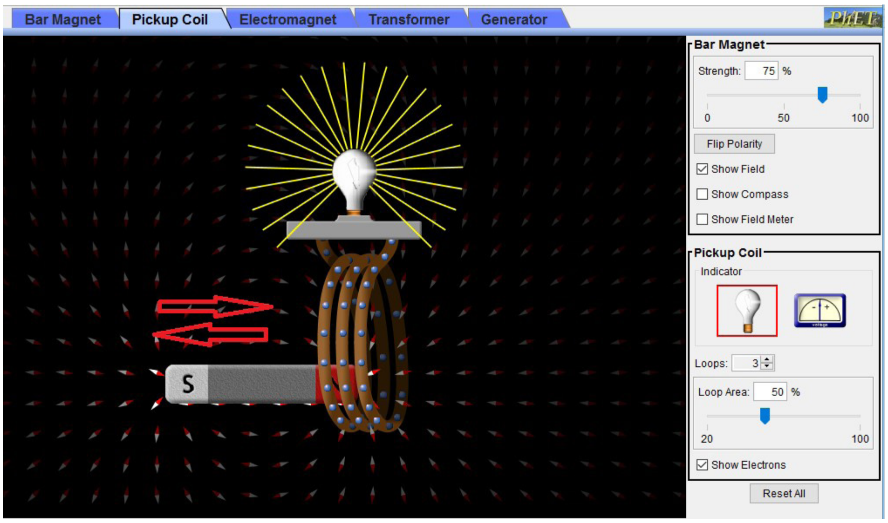


(b)

Figure 3. The light of lamp is on when a bar magnet is moved in and out of the coil with (a) slow motion and (b) fast motion



(a)



(b)

Figure 4. The light of the lamp when the bar magnet is moved in and out of the coil with (a) two turns and (b) three turns

Experiment 4c – Effect of Magnetic Field Strength on the Induced Current Strength

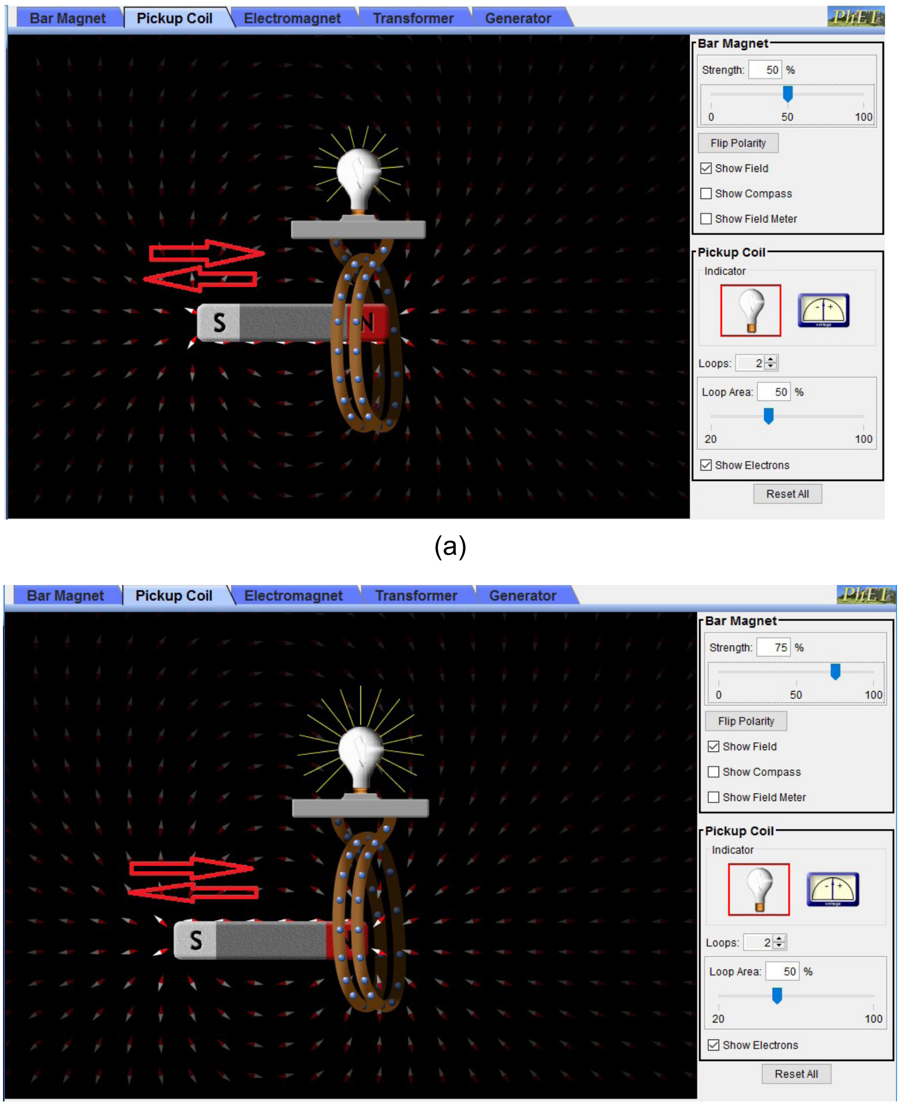
Students conducted experiments, as shown in Figure 4. Students determined the magnetic field strength as an independent variable, the speed of magnetic motion and the number of turns as control variables, and the induced current strength as a dependent variable. Then, the observation table was filled out by students. The speed of the magnetic motion was determined as fixed, and the number of turns was determined as fixed with two turns, and the bar magnet was moved (in and out) of the coil with a magnetic field strengths were at 25%, 50%, and 75%. Based on observations, students stated that when the bar magnet with different magnetic field strengths (25%, 50%, and 75%) was moved in and out of the coil, the lamp was on. All students then concluded that a lamp would be on brighter when a bar magnet with a magnetic strength of 75% is moved in and out of a coil than the bright of the lamp when the bar magnet with a magnetic strength of 50% is moved in and out of the coil. Moreover, the lamp would be brighter when the bar magnet with a magnetic strength of 50% is moved in and out the coil than the bright of the lamp when the bar magnet with a magnetic strength of 25% is moved in and out of the coil. Students were then informed that the lamp that was on indicated that there was an induced current in the coil (Elok, Widodo, Wasis, & Suhartanti, 2008). The brighter the lamp, the greater of induced current in the circuit.

Based on observations in Experiment 4a, Experiment 4b, and Experiment 4c, all students concluded that there were three factors that influenced the strength of the induced current, namely (1) the speed of magnetic motion which the faster of magnetic motion (in and out) in the coil, the greater induced current strength generated; (2) the number of turns which the higher the number of turns, the greater the induced current; and (3) the strength of the magnetic field which the greater of magnetic field strength in the coil, the stronger of induced current.

After experimenting, students were asked to explain again about the magnitude and direction of the magnetic field, and 57% of students (eight students) were able to explain to them while 43% of students (six students) were not able to respond.

The learning design on Faraday's Induction Law using the PhET simulation of Faraday Electromagnetic Lab, as shown above, was effectively used to help students understand Faraday's Induction Law material. The conclusion from the results of each learning has been in accordance with the existing theory, where the results of learning about Electromagnetic Induction in Activity 4 have been in accordance with the learning results of Electromagnetic Induction using real laboratory equipment, i.e. the faster of magnetic motion on the same number of turns, the greater of induced ggl generated and the more of number of turns in the coil for the same magnetic motion speed, the greater of the induced ggl (Amelia, Rustana & Nasbey, 2015).

The learning design on Faraday's Induction Law using the PhET simulation of Faraday



(a)

(b)

Figure 5. The light of the lamp when the bar magnet with magnetic strength (a) 50% and (b) 75% is moved in and out of the coil

Electromagnetic Lab, as shown above, was effectively used to help students understand Faraday’s Induction Law material. The conclusion from the results of each learning has been in accordance with the existing theory, where the results of learning about Electromagnetic Induction in Activity 4 have been in accordance with the learning results of Electromagnetic Induction using real laboratory equipment, i.e. the faster of magnetic motion on the same number of turns, the greater of induced ggl generated and the more of number of turns in the coil for the same magnetic motion speed, the greater of the induced ggl (Amelia, Rustana & Nasbey, 2015).

Result of Learning Observations

Results of learning observations that are based on the learning activities observation sheet are shown in Table 1. The results of the learning activity observation in Table 1 show that in Activity 1, all students (100%) gave positive responses to the learning activities that were conducted. The motivation given by the teacher made students to be motivated to learn (M1); questions are given by the teacher successfully stimulated students to submit hypotheses (M2). Students also could make observations and write down their observations regarding the experiments that were conducted (M3); they dared to express their opinions and draw conclusions from the conducted experiments (M4). They were able to explain the results of their learning to their classmates by using their sentences.

However, in Activities 2, 3 and 4, only 57% of students (8 students) were willing to explain the results of their learning to their classmates, though in step M3 and M4 in each activity, all students could adequately follow up the learning conducted by the teacher.

Table 1. Results of Learning Activities Observation

Activity	Number of Student (%)			
	1	2	3	4
M1	100.0	100.0	100.0	100.0
M2	100.0	100.0	100.0	100.0
M3	100.0	100.0	100.0	100.0
M4	100.0	100.0	100.0	100.0
M5	100.0	57.0	57.0	57.0
Mean	100.0	91.4	91.4	91.4

M1: Observing; M2: Asking questions; M3: Trying; M4: Reasoning; M5: Communicating.

Although in three activities, several students did not want to explain again about what they have learned in the learning (M5), the mean results of learning activities observation for the learning that was designed show that 91.4% -100% of students were able to follow the learning well. Therefore, it can be said that ≥70% of all students responded positively toward the earning activities that were carried out in each activity. In this case, the learning design of Faraday's Induction Law using a PhET simulation of Faraday's Electromagnetic Lab was effective in helping the students to understand the material (Purwanto, Hendri, & Susanti, 2016).

Observation Results of Student Attitudes

The observation results of student attitudes (student enthusiasm and activeness) based on the learning activity observation sheet, as shown in Table 2. Student enthusiasm for learning material is shown through several responses. Namely, students pay attention to the teacher's explanation, students take note or record the material given, and students ask questions about the material given. The student activeness is indicated through several responses. Namely, students answer all follow-up questions made by the teacher.

Table 2. Observation Results for Student Attitudes

Student Attitude	Number of Student (%)	
Enthusiasm	79	11 students
Activeness	74	10 students

The observation results of student attitudes in Table 2 show that eleven students were enthusiastic about the material provided by the teacher, and ten students were active in participating in the learning activities. Thus, it can be said that ≥70% of all students got to score ≥70 on each attitude assessment item so that the learning design of Faraday's Induction Law using a PhET simulation of Faraday’s Electromagnetic Lab was effectively used to help students understand the Faraday’s Induction Law material.

Evaluation Results of Student Cognitive

The results of students' cognitive evaluation are based on the results of the exercise questions in class, as shown in Table 3. The results of the students' cognitive evaluation

Table 4. Results of Questionnaire Analysis

Statement	TS (%)	S (%)
I can observe the existence of the magnetic field and the fluctuating of the magnetic field when I learn the material using a PhET simulation.	7	93
I can understand the material of Faraday's Law when I learn the material using a PhET simulation.	14	86
I am excited to learn the material of Faraday's Law using a PhET simulation.	7	93
I am more enthusiastic about learning the material of Faraday's Law using PhET simulation.	14	86

test in Table 3 show that all students (100%) obtain test scores of 75-88. It shows that students had good learning outcomes and the learning media (PhET simulation) are proven to be helpful for students to understand the material provided by their teacher. Thus, ≥70% of all students obtain ≥ 70 test scores. Thus, the learning design of Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab is said to be effectively used to help students understand Faraday's Induction Law material.

Table 3. Evaluation Results of Student Cognitive

Group	Score
A	75
B	87.5
C	78.125
D	78.125

Questionnaire Analysis Results

There are four statements required by students to be filled out in the questionnaire, as shown in Table 4.

The results of the questionnaire analysis show that in each statement of the questionnaire, ≥70% of all students gave positive responses toward ≥70% statements in the questionnaire. Thus, the learning design of Faraday's Induction Law using a PhET simulation of Faraday's Electromagnetic Lab is said to be effectively used to help students understand Faraday's Induction Law material.

Based on the results of learning activities observation, it shows that 91.4-100% of learning steps were followed by students well. Whereas based on the observation sheet of student attitudes, the PhET virtual laboratory had made 79% of all students were enthusiastic, and 74% of all students were active in conducting the Faraday's Induction Law experiments. Based on the results of the cognitive evaluation, all students managed to obtain test scores of 75-88. In the questionnaire, 86-93% of all students stated that the PhET simulation helped them in observing and understanding concepts involving abstract variables such as magnetic fields and changes in magnetic flux (Cwew & Wee, 2015). Thus, they were happy and more enthusiastic when they learned the material of Faraday's Induction Law using the PhET simulation. Thus, all criteria of successful research are achieved so that the learning design of Faraday's Induction Law using the PhET simulation of Faraday's Electromagnetic Lab is said to be effectively used to help students understand Faraday's Induction Law. Thus, although the experiments of Faraday's Induction Law cannot be done directly in a real laboratory due to limited laboratory equipment, the PhET simulation can be used as an alternative learning medium of Faraday's Induction Law.

CONCLUSION

The learning design of Faraday's Induction Law in the form of a Learning Implementation Plan using the PhET Simulation of Faraday's Electromagnetic Lab is effectively used to help students understand the Faraday's Induction Law material. Similar researches that apply PhET simulation can be done for other Physics materials. In addition, to be a learning medium for learning activities in a class, a module can also be made to create independent learning activities outside the class learning using PhET simulation.

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