Indonesian Journal of Science and Education
Volume 4, Nomor 1, 2020, pp: 12~29
ISSN: 2598-5213, e-ISSN: 2598-5205, DOI: 10.31002/ijose.v4i1.1294
e-mail: ijose@untidar.ac.id, website: jurnal.untidar.ac.id/index.php/ijose

Designing Independent Practicum Module about Photoelectric Effect Using PhET Simulation

Sita Aryani[1], Debora Natalia Sudjito[2], Alvama Pattiserlihun[3]
Department of Physics Education, Faculty of Science and Mathematics
Universitas Kristen Satya Wacana Salatiga
e-mail: [2]debora.natalia@staff.uksw.edu

Received: April, 24th 2019 *Revised: February 26th 2020* *Accepted: April 4th 2020*

ABSTRACT

Learning about Photoelectric Effect involves various interesting physical quantities to be deeply studied. Due to the limitations of laboratory tools, the Physics Education Technology (PhET) Interactive Simulations is needed as a virtual laboratory. In order for students to independently study the Photoelectric Effect material using PhET simulation, a guide is needed in the form of independent practicum module. This study examines the effectiveness of the design of independent practicum module using PhET simulation for student understanding of Photoelectric Effect concept. Respondents in this study were 4 students of the first level of Physics and Physics Education Department in Salatiga – Central Java. The method used is descriptive research with instruments in the form of observation sheets, evaluation questions, questionnaires, and interviews. The results are all students were able to follow the steps in the module properly and each student was able to answer module questions correctly by ≥ 70% of 100%; they got score ≥ 70 of 100 with an average score of 91.25 overall; and they gave a positive response of ≥ 70% of 100% for each indicator given. Thus, the independent practicum module using the PhET simulation can be said to be effective in helping students explore the material of Photoelectric Effects independently and it can be developed for HOTS learning.

Keywords: *Photoelectric Effect, PhET simulation, independent practicum module*

INTRODUCTION

Learning about Photoelectric Effect involves various interesting physical quantities to be deeply studied. In general, based on the experiences of the lecturers in the respondents' university, learning about Photoelectric Effect can be done through lectures, assignments or practice presentations, simulations, or experiments in the laboratory. These methods are combined to effectively help students understanding the abstract material. The Photoelectric Effect tells us about the behavior of particles that are invisible because they are micro-sized, making it difficult to observe and can be said to be abstract. Therefore laboratory equipment for practicum and simulation is considered very helpful for students to study the Photoelectric Effect. But in reality, laboratory equipments for practicums and simulations that can be used in lectures are limited, expensive, and some are not available (Setiawan, A., Suyatna, A., Abdurahhman, 2016).

To overcome this limitation, learning media is needed as an experimental aid in the form of a virtual laboratory. In this study, Physics Education Technology (PhET) Interactive Simulations is used as virtual laboratory application. According to several related studies, PhET simulations are very effective and really help students understanding the concepts of Physics (Setiawan, Suyatna, Abdurahhman, 2016; Hapsara, Karanggulimu, Sudjito, Noviandini, 2017; Dinavalentine, Sudjito, Noviandini, 2016; Indriyani, 2016.) Therefore, the PhET simulation was used in this study.

Learning using PhET simulation requires a long study time, learning in the classroom is apparently not sufficient to make students comprehensively understand the lecture material (Indriyani, 2016), especially about the Photoelectric Effect. Students need additional time to be able to learn the effect of variable changes on the Photoelectric Effect.

One of the research related to the use of PhET "Photoelectric Effect" simulations in the learning of modern physics is research by Hapsara, et al (2017). The research examined the effectiveness of using PhET as a virtual laboratory on the photoelectric effect during face-to-face lectures in class with an allocation of 100 minutes. However, face-to-face learning in the classroom is apparently not enough. Students need additional time to be able to learn the effect of variable changes on the Photoelectric Effect. In order for students to learn about Photoelectric Effects independently outside face-to-face lectures, the use of PhET should be followed by instruction which is made in the form of an independent practicum module so that student self-learning can be more directed and structured. In addition, the independent practicum module can also be used by teachers to provide assignments at home for students to interact more frequently with PhET. This is done so that students can find, explain, or construct reasons and opinions about the importance of physics concepts in their daily lives. This research presents the design of an independent practicum module on the Photoelectric Effect using a PhET "Photoelectric Effect" simulation to guide students in learning about the photoelectric effect independently which can be used as strutured assignment for students. (Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R., 2006). The use of practicum modules is very effective to guide students to do practicum independently and facilitate students to study Physics materials using PhET simulations. The use of practicum modules is very effective to guide students to do practicum independently and facilitate students to study Physics using PhET simulations (Karanggulimu et al., 2017; Dinavalentine et al., 2016).

This study presents the effectiveness of an independent practicum module on the Photoelectric Effect using the PhET simulation towards students understanding. This reseacrh aims (1) to design an independent practicum module on the Photoelectric Effect using the PhET Photoelectric Effect simulation and (2) to investigate the effectiveness of the independent practicum module design about Photoelectric Effect using PhET simulation towards students' understanding. This study also has the benefit of (1) enriching the diversity of independent practicum modules that can be used by students, especially in Modern Physics and (2) providing guidance for students to explore material about Photoelectric Effects independently which can be used as structured tasks and independent learning outside of face to face lectures.

RESEARCH METHODS

The research method used is descriptive research (Karanggulimu et al., 2017; Dinavalentine et al., 2016). The instruments used are 1) **observation sheet** to record the process of an independent practicum running using an independent practicum modules with PhET simulations, 2) **evaluation questions** to determine respondents understanding about Photoelectric Effect after using an independent practicum module with PhET simulation, 3) **questionnaires** to view responses about independent practicum modules, 4) **interviews** to determine the difficulties that respondents and obtain suggestions for improving their modules. The results of the evaluation questions and questionnaire will be analysis with score based on conditions Table 1.

Table 1. Coding of Respondents' Responses

Category	Score
Totally Agree	4
Agree	3
Not Agree	2
Disagree	1

Source: Riduwan (2011)

Then, calculate the percentage with the following conditions:

Table 2. Score Guidelines

Percentage (%)	Category
100 - 76	Very Good
75 – 51	Good
50 - 26	Less
25- 0	Very Poor

The respondents in this study are four (4) freshmen of Department of Physics Education. All data that were analyzed descriptively and qualitatively to determine the effectiveness of the module towards students' understanding about concepts of Photoelectric Effect. Modules are said to be effective if all respondents (1) can work at least 70% of practicum activities correctly according to the module guidelines based on observations, (2) provide positive feedback on minimum of 70% statements about practicum modules based on questionnaires, and (3) get grades of evaluation questions of at least 70 out of 100.

RESULTS AND DISCUSSION

Before the practicum began, students installed Physics Education Technology (PhET) simulation on their laptops. After successfully installing, students were informed about how to use it and the components contained in the PhET simulation as shown in Figure 1. Then students were given an independent practicum module about the Photoelectric Effect.

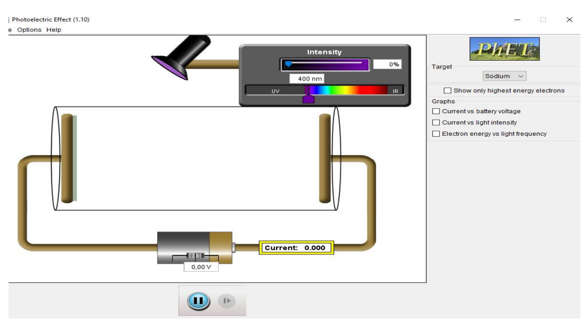

Figure 1. Display of PhET "Photoelectric Effect" simulation after installed

Activity 1. Definition of Photoelectric Effects

To investigate the meaning of Photoelectric Effects, students were given steps in simulating of PhET. In the module, students were assigned to set the light wavelength of 400 nm, the light intensity of 100%, metal material in the form of sodium, and select the "Play" button. Then students observed changes in electric current.

Based on observations during Activity 1, students were able to follow the steps in accordance with the module and answer the questions correctly. In the module, students were given guiding questions to draw conclusions: *"When a metal plate (sodium) is illuminated by photon light, what happens to the metal plate? When a metal plate is illuminated by light, is there an electric current flowing?"*. All students (100%) answer correctly that there was an electric current flowing.

PhET simulation provides concrete observations in helping students on the Photoelectric Effect event. Guiding questions also helped students to analyze based on observational data obtained by students through PhET. This shows that Activity 1 effectively has made students know the meaning of the Photoelectric Effect.

Activity 2. Factors Affecting the Amount of Released Electrons

To investigate the effects of variable changes, students were informed about the definition of independent variables, dependent variables, and control variables in the module.

a. The Effect of Voltage Towards of Released Electrons

To determine the effect, students determined the variables to be used in the activity. All students (100%) were able to determine control variables, independent variables, and dependent variables used for simulation.

After determining the variables, the students arranging sodium as metal, light intensity of 85%, light wavelength of 298 nm, select "Current vs. Battery Voltage" to find the graph of the voltage relationship with the number of the released electrons, which voltage set from 0 to 6 *V*, then students observed the results of the electric current measurement in the PhET simulation as shown in Figure 2 and filled out tables available in the module.

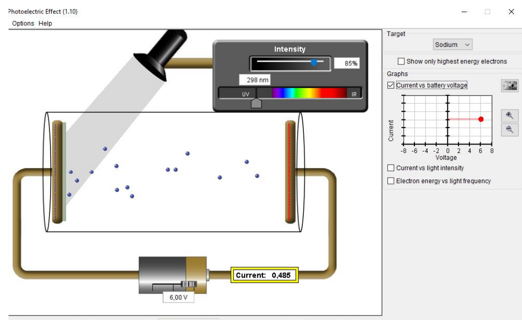

Figure 2. Results of Activity 2a in the PhET simulation

Based on observations, all students (100%) were able to determine the number of electric current correctly. Then students were given questions: *"When the voltage is enlarged from 0 to 6 V, what is the magnitude of the electric current? Is it bigger, smaller, or fixed? based on "Current vs. Battery voltage" graph, how does the voltage affect the number of the released electrons?"*. All students (100%) were able to answer the question correctly and conclude that the voltage does not affect the amount of electrons that are released. This shows that Activity 2a helps students understand that electric voltage does not affect the number of the released electrons.

b. The Effect of Metal Types Towards of Released Electrons

Before Activity 2b began, students determined the independent variable, dependent variable, and the control variable. After determining the variables, students did simulation by arranging sodium as metal, light intensity of 75%, light wavelength of 180 nm, voltage of 0 volt, and recording the results of electric current measurement into a table provided in the module. In addition, students repeated these steps for other metals.

Based on observations during Activity 2b, students were able to follow the steps in accordance with the module and answer the questions correctly. In the module, students were given questions: *"Is the amount of electric current the same for each type of metal? Which type of metal produces the most electrical current?, Which type of metal produces the smallest electric current ?, Does the type of metal that produces the smallest electric current also produces the least number of the released electrons?, and So, does the type of metal affect the number of the released electrons?"*. All students (100%) were able to answer these questions correctly and conclude that the type of metal affects the number of the released electrons.

PhET simulation provides concrete observations in helping students to analyze the effect of metal types on the number of the released electrons. The Guiding questions also help students to analyze based on observational data obtained by students through PhET. This shows that Activity 2b effectively helps students in determining the effect of metal types on the number of the released electrons.

c. The Effect of Light Intensity Towards of the Released Electrons

Before Activity 2c started, students determined the independent variable, dependent variable, and the control variable. All students were able to determine the variables correctly. After determining the variables, the students did simulation as shown in Figure 3 by arranging sodium as a metal, light wavelength of 180 nm, voltage of 0 volt, then select "Current vs Intensity Light" in the graph selection to find out the relationship of light intensity towards the number of electrons released, changed the intensity light from 0% to 100%, and recorded the measurement results of electric current in a table provided in the module.

Based on observations during Activity 2c, students were able to follow the steps in the module, and answer the questions correctly.

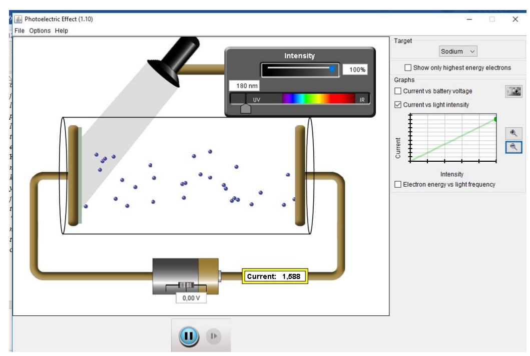

Figure 3. Display of Activity 2c results in the PhET simulation

In the module, students were given questions: *"When the light intensity is increased, is the magnitude of the electric current getting bigger, smaller, or fixed? Based on "Current vs. Intensity Light" on the graph, how is the light intensity related to the number of the released electrons?"*

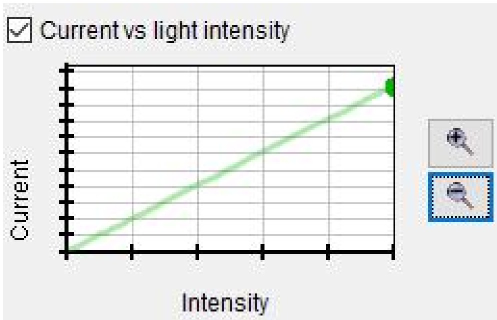

Figure 4. Graph of the Relationship of Light Intensity to Electric Current

"So, does the light intensity affect the number of the released electrons?" All students (100%) were able to answer these questions correctly and they were able to conclude that light intensity affects the number of the released electrons.

PhET simulation provides a concrete observation in helping students analyze the effect of light intensity on the number of the released electrons. The Guiding questions also help students to draw conclusion. This shows that Activity 2c effectively helps students in determining the effect of light intensity on the number of the released electrons.

d. The Effect of the Light Wavelength Towards of the Released Electrons

Before Activity 2d began, students determined the independent variable, dependent variable, and the control variable. After determining the variables, students did simulation by arranging sodium as a metal, voltage of 0 volt, light intensity of 80%, and changed the wavelength from 480 nm to 600 nm, then observed the number of the released electrons in the PhET simulation and recorded the results of observations in a table provided in the module.

Based on observations during Activity 2d, students were able to follow the steps in the module and answer questions correctly. After doing the simulation, student's answered the guiding questions in order to conclude: *"How many are the released electrons from each change in light wavelength ranging from 480 nm to 600 nm? Are they more, less, or still in number? What is the wavelength of sodium material which the electrons are not released anymore? Does the light wavelength affect the number of the released electrons?"*. All students (100%) were able to answer these questions correctly and conclude that wavelength can affect the number of the released electrons.

The PhET simulation provides a concrete observation in helping students analyze the effect of light wavelength on the number of the released electrons. The Guiding questions also help students to analyze based on the observational data obtained by students through PhET and draw conclusions. This shows that Activity 2d effectively helps students to determine the effect of light wavelength on the number of the released electrons.

e. The Effect of Electric Current Towards of the Released Electrons

In Activity 2e, students no longer determined the variables to be used but directly answer the questions provided in the module: *"Based on Activities 2a to 2d, can the electric current be used as an indicator of the number of the released electrons?"*, All students (100 %) answer correctly that electric current can be used as an indicator of the number of the released electrons. *"How does the electric current relate to the number of the released electrons?"*, All students (100%) answer correctly that the more electric current flows, the more electrons are released. *"So, does the electric current affect the number of the released electrons?"*, Only one student (25%) answer correctly that electric current does not affect the number of the released electrons but only used as an indicator of the number of released electrons while the other three students answer incorrectly. Based on the results of interviews, students (respondents) claimed that they were confused in determining the effect of electric current on the number of the released electrons. Students assumed that if an electric current is used as an indicator of the number of the released electrons, the electric current also affects the number of the released electrons. This shows that Activity 2e failed to make students understand the effect of electric current on the number of the released electrons. However, three students (75%) were able to answer correctly. Overall, Activity 2 helps students to understand properly that the factors influencing the number of the released electrons are voltage, wavelength, and light intensity.

Activity 3. Factors Affecting Threshold Wavelength (λ_0)

Before investigating the factors that influence the threshold wavelength (λ_0) using PhET simulation, students were informed that the wavelength of the threshold (λ_0) is the largest wavelength needed to release electrons from a metal surface when reaching a certain maximum wavelength, electrons are no longer come out of a metal surface.

a. The Effect of Metal Types on Threshold Wavelength (λ_0)

Before Activity 3a began, students determined the independent variable, dependent variable, and the control variable. After determining the variables, students did simulation by arranging sodium as a metal, a voltage of 0 volt, a light intensity of 100%, and changed wavelength from 100 nm to 850 nm, then observed the threshold wavelength and filled out a table provided in the module.

Based on observations during Activity 3a, students were able to follow the steps of simulation in the module properly.

Table 3. The Experiment Results of (λ_0) for Types of Metal

Type of Metal	Threshold wavelength (nm)
Sodium	540
Zinc	289
Copper	264
Calcium	428
Platinum	198

In the module, students were given questions to draw conclusion: *"Does each type of metal have the same threshold wavelength (λ_0)? So, does the metal type affect the value of the threshold wavelength (λ_0)?"*. All students (100%) were able to answer the question correctly and conclude that the type of metal affects the number of the threshold wavelength (λ_0).

PhET simulation provides concrete observations in helping students to analyze the effect of metal types on threshold wavelength. Guiding questions also help students to draw conclusions. This shows that Activity 3a is effective in helping students determine the effect of metal types on threshold wavelength (λ_0).

b. The Effect of Light Intensity on Threshold Wavelength (λ_0)

Before Activity 3b began, students determined the independent variable, dependent variable, and the control variable. After determining the variables, students carried out a simulation by arranging sodium as metal, voltage of 0 V, wavelength of 540 nm, and changed the intensity of light from 20% to 80%, then observed the threshold wavelength and filled out a table provided in the module.

Based on observations during Activity 3b, students were able to follow the simulation steps well. In the module, students were given the questions: *"At each increase in light intensity, is the threshold wavelength of sodium getting bigger, smaller, or fixed? So, does the intensity of light affect the threshold wavelength?"*. All students (100%) were able to answer correctly and were able to conclude that light intensity does not affect the threshold wavelength (λ_0).

PhET simulation provides concrete observations in helping students analyze the effect of light intensity on threshold wavelength. Guiding questions also help students to analyze based on the observational data obtained by students through PhET in order to conclude. This shows that Activity 3b effectively helps students to determine the effect of light intensity on the threshold wavelength (λ_0).

c. **The Effect of Voltage on The Threshold Wavelength (λ_0)**

Before Activity 3c began, students determined the voltage as independent variable; light intensity and metal material as control variables, and the threshold wavelength as the dependent variable. All students (100%) were able to determine the variables correctly. Students did simulation by arranging sodium as metal, wavelength of 540 nm, and light intensity of 100%, changed the voltage from 0 to 8 V, then observed the value of the threshold wavelength (λ_0) and filled out a table provided in the module .

Based on observations during Activity 3c, students were able to follow the simulation steps well. In the module, students were given the questions: *"When the voltage is increased from 0 to 8 V, what is the value of the threshold wavelength (λ_0), is it larger, smaller, or fixed?, Does the voltage affect the value of the threshold wavelength (λ_0)?"*. All students (100%) were able to answer the question correctly and conclude that the voltage does not affect the threshold wavelength (λ_0). This shows that Activity 3c effectively helps students understand the effect of voltage on the threshold wavelength (λ_0).

Overall, Activity 3 effectively helps students to understand that the factors that influence the threshold wavelength (λ_0) is type of metal.

Activity 4. Determining the Maximum Kinetic Energy of the Releasing Electrons

a. Determining the Kinetic Energy of the Released Electrons

Before simulation began, in the student module, it was informed that in order that photons can come out from a metal surface, a higher energy is needed from its electron bonding. The kinetic energy equation is as follows:

$$EK = \frac{1}{2}mv^2 \tag{1}$$

Where m is mass, and v is the velocity of the electron. Before knowing the amount of kinetic energy needed by the released electrons, students must first know the velocity of each released electron. In Activity 4a, students no longer determined the variables to be used. Students immediately carried out simulations by arranging sodium as metal, voltage of 0 *V*, a light intensity of 30%, and wavelength of 400 nm. Then students observed the electron velocity released in the PhET simulation as shown in Figure 5.

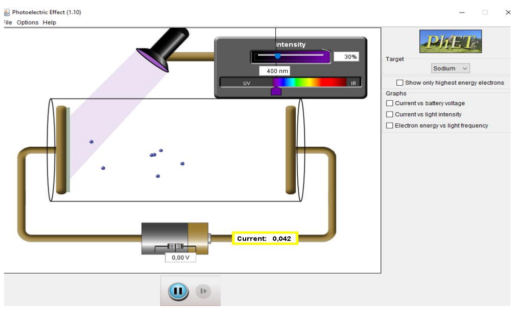

Figure 5. Display of Activity 4a results in PhET Simulation

Based on observations during Activity 4a, students were able to follow the module steps well and answer the questions: *"Does each electron that is released have the same velocity? Based on equation (1), what is the kinetic energy of each electron? Is it same or different?"*. All students (100%) answer correctly that the velocity of released electrons varies so that the kinetic energy of each electron also varies.

PhET simulation provides concrete observations in helping students determine the kinetic energy of each electron. Guiding questions also help students to analysis based on the observational data obtained and draw conclusions. This shows that Activity 4a effectively helps students determine the kinetic energy of released electrons using PhET simulation.

b. Determining the Stop Potential (V_0)

Before Activity 4b began, students were given questions in the module to recall the results of observations from Activity 2a which show that when the voltage is increased, the value of the electric current remain indicating the presence of flowing current or electrons coming out of the metal surface. Then students were given stimulant questions about what happens if the voltage is reduced bit by bit. All students (100%) were able to answer the questions correctly.

To find out the stop potential, students first determined the variables to be used. After determining the variable, the student performed Activity 4b using the Ph.ET simulation by arranging sodium as metal, the intensity of light at 100%, light wavelength at 298 nm, and changed the voltage from 0 to -2.0 V. Then observed and filled out table of light current measurement results provided in the module.

Table 4. Results of Measurement *I* on particular *V*

Volt (V)	Current (A)
0	0.569
-0.40	0.446
-0.80	0.324
-1.20	0.202
-1.60	0.80
-2.00	0

Based on observations during Activity 4b, students were able to follow the module steps properly and answer the questions correctly. In the module, it was informed the meaning of stop potential (V_0). *"Based on the following explanation, how much is the stop potential (V_0) on sodium material?"*. All students (100%) were able to answer correctly. In the module, it was informed that the potential difference depends on the amount of the released electron charge from a metal plate. Thus, the relationship of maximum kinetic energy with potential energy can be written as follows:

$$EK_{max} = Ep \quad (2)$$

$$EK_{max} = eV_0 \quad (3)$$

Explanation:
EK_{max} = Maximum kinetic energy (J)
Ep = Potential energy (J)
e = Electron charge
= (1.6×10^{-19} kg/m^3)
V_0 = Stop potential (V)

The equation (3) shows that the maximum kinetic energy value is directly proportional to its potential energy. This means that maximum kinetic energy can be measured by determining its stop potential.

PhET simulation provides concrete observations in helping students determine stop potential (V_0). The guiding questions also help students to analyze and conclude. This shows that Activity 4b effectively help students in determining stop potential (V_0).

Activity 5. Factors Affecting Maximum Kinetic Energy

a. The Effect of Light Intensity on Maximum Kinetic Energy of Electron

To be able to investigate the effect of light intensity on electron maximum kinetic energy, students must first determine the variables to be used in Activity 5a. After determining the variables, students did simulation by arranging sodium as metal, the wavelength was arranged at 298 nm, the voltage at -2.0 V, and changed the light intensity from 50% to 100%. They observed the results of stop potential measurement and filled out a table provided in the module.

Based on observations during Activity 5a, students were able to follow the module steps properly. After doing the simulation, students answer the questions: *"When the light intensity increases, how much is the potential value, is it bigger, smaller or fixed? Does the intensity of light affect the amount of stop potential? If the stop potential is proportional to its maximum kinetic energy, does the light intensity also affect the maximum kinetic energy?"*. All students (100%) were able to answer correctly and were able to conclude that light intensity does not affect the maximum kinetic energy of electron.

PhET simulation provides concrete results in helping students determine the effect of light intensity on maximum kinetic energy. The Guiding questions also help students to analyze and conclude. This shows that Activity 5a effectively helps students in determining the effect of light intensity on maximum kinetic energy.

b. The Effect of Light Wavelength on Maximum Kinetic Energy of Electron

Students determine the variables to be used in Activity 5b. After determining the variables, students ran the PhET simulation by arranging sodium as metal, wavelength was changed from 200 nm to 400 nm. Then they changed the voltage from 0 to -8.00 V, and observed the value of its stop potential and write the results of voltage or stop potential measurement as shown in Table 3.

Table 5. Results of Measurement of V_0 for particular λ

Wavelength (nm)	Stop Potential (V)

200	-4.00
300	-2.00
400	-0.80

Based on observation during Activity 5b, students were able to follow the steps in the module. After the simulation, students answer the following questions: *"When the value of the wavelength is increased, how is its potential value, is it larger, smaller, or fixed?, If the potential is proportional to maximum kinetic energy, how much is the value of its maximum kinetic energy? Is it bigger, smaller, or fixed? Then, does the light wavelength affect the magnitude of maximum kinetic energy? How is the relationship between maximum kinetic energy and the light wavelength, is it proportional or inverse?"*. Two students (50%) were able to answer all questions correctly, while the other two students (50%) answer incorrectly. The two wrong students assumed that the wavelength is directly proportional to the maximum kinetic energy. However, all students (100%) were able to conclude that wavelength affects maximum kinetic energy.

PhET simulation provides concrete observations in helping students determine the effect of light wavelength on maximum kinetic energy. The Guiding questions also help students to analyze based on the observational data obtained by students through PhET in order to draw conclusions. This shows that Activity 5b effectively helps students find out the effect of light wavelength on maximum kinetic energy.

c. The Effect of Light Frequency on Maximum Kinetic Energy

Before simulation, the module informs about the relationship of frequency (f), light wavelength (λ), and light velocity (c) through the light velocity equation as follows:

$$c = \lambda \times f \tag{4}$$

or

$$f = {}^{1}/_{\lambda} \tag{5}$$

Equation (5) shows that the light frequency is inversely proportional to the light wavelength. In addition, there were several Guiding questions in the module as follows: *"If the light frequency is inversely proportional to the light wavelength, what will happen to the light frequency when the wavelength is smaller? What will you do for the value of light wavelength to increase the light frequency when f~1/λ?"*. All students (100%) were able to answer the question correctly that the smaller wavelength, the greater its frequency, so that to increase the light frequency, the wavelength value must be increased.

To be able to investigate the effect of frequency on maximum kinetic energy of electrons, students must first determine the variables to be used in Activity 5c. After determining the variables, students ran the PhET simulation by arranging sodium as metal, light intensity of 100%, voltage of -2.0 V, chose "Electron Energy vs. Light Frequency" graph to find relationship of light frequency to maximum kinetic energy of electrons from the PhET simulation, reduced the light wavelength from 800 nm to 100 nm. Then they observed the measurement results in graphical as shown in Figure 6 and recorded the results of the maximum kinetic energy measurement at a particular frequency into a table provided in the module.

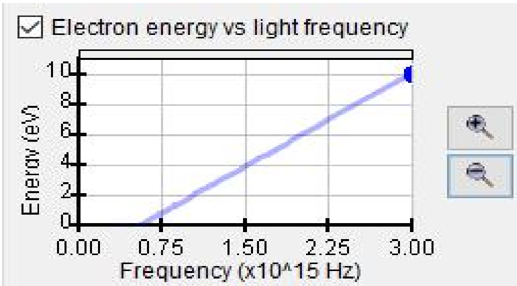

Figure 6. Graph of the relationship f to EK_{max}

Based on observations during Activity 5c, students were able to follow the module steps properly and answer the questions: *"Based on the results of the graph of Electron Energy vs. Light frequency on PhET, what is the maximum kinetic energy of the electron when the light frequency is less than 0.75 × 10^{15} Hz; 1.5 × 10^{15} and 3 × 10^{15}?"*

Table 6. Measurement Results of Ek_{max} for a particular f

Light Frequency (Hz)	Maximum Kinetic Energy (eV)
<0.75 × 10^{15}	0
1.5 × 10^{15}	4
3 × 10^{15}	10

"Based on the results you get, with the increasing of light frequency, how does it influence on the maximum kinetic energy of the electron? Is it bigger, smaller or fixed? Does the light frequency affect maximum kinetic energy? How does the light frequency relate to the maximum kinetic energy of electron? Is it directly proportional or inversely proportional?", All students (100%) were able to answer the questions correctly and were able to conclude that the light frequency can affect maximum kinetic energy which the greater of light frequency, the greater the maximum kinetic energy of the electron, and mathematically it is obtained as:

$$EK_{maks} \sim f \quad (6)$$

PhET simulation provides concrete observations in helping students determine the effect of light frequency on maximum kinetic energy. The Guiding questions also help students to analyze based on the observational data obtained by students through PhET in order to draw conclusions. This shows that Activity 5c effectively helps students to understand the effect of light frequency on maximum kinetic energy.

Overall, Activity 5 effectively helps students to understand that the factors influencing maximum kinetic energy are light frequency and light wavelength.

Activity 6. The Relationship of Electron Kinetic Energy and Incoming Light Energy and Work Function

Before investigating the relationship of electron kinetic energy and incoming light energy and work function, the module informs about the requirements for the Photoelectric Effect. In order for a Photoelectric Effect to occur, a metal plate must be illuminated and meet the light frequency requirement that illuminates the cathode which must be greater than the material threshold frequency ($f > f_0$) or which the light wavelength that illuminates the cathode must be smaller than the wavelength of metal material threshold ($\lambda < \lambda_0$). In addition, students were able to find the maximum kinetic energy equations using kinetic energy relation graph with the frequency generated from Activity 5c simulation.

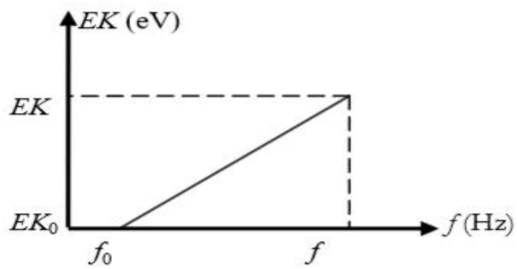

Figure 7. Graph of Relationship f to EK

Using the gradient equation, it is obtained that:

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$
$$m = \frac{EK - EK_0}{f - f_0}$$
$$EK - 0 = m(f - f_0)$$
$$EK = mf - mf_0$$

Thus, the electron kinetic energy equation becomes:

$$EK_{maks} = hf - hf_0 \qquad (7)$$

Explanation:
EK = Maximum electron kinetic energy (J)
h = Planck constant (6,626 × 10^{-34} J.s)
hf = Incoming light energy (eV)
hf_0 = The minimum energy needed to release electrons from the metal plate (eV)

The module informed students that electron kinetic energy comes from the incoming light energy (hf). The incoming light energy is used to release electrons to the crossing plate and to move electrons from the metal surface. To remove electrons from the metal surface, minimum energy is needed. The minimum energy required for releasing electrons from the binding energy of hf_0 can also be called a work function (W). If the incoming light energy is less than its minimum energy or its working function ($hf < W$), the Photoelectric Effect does not occur; if the incoming light energy is greater than its minimum energy or its working function ($hf > W$), the Photoelectric Effect will occur where the electrons will emerge from the surface of the metal and the excess energy will change to kinetic energy. Thus, the relationship between incoming light energy, work function, and maximum electron kinetic energy can be expressed as an equation:

$$EK_{max} = hf - W \qquad (8)$$

Explanation:
EK_{max} = Electron kinetic energy (J)
hf = Energy of Incoming light (J)
W = Work Function (J)
1 eV = 1.6 x 10^{-19} J (J)

If they are given a wavelength (λ), students can replace f. Because $f = c/\lambda$, then equation (7) can be written as:

$$EK_{maks} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} \qquad (9)$$

where h is Planck's constant (h = 6,626 x 10^{-34} $J.s$)

Activity 7. Investigating the Nature of the Light of Photoelectric Effect

In this activity, students first answer questions to guiding them to simulate investigation about the nature of light of Photoelectric Effect using PhET. *"In Activity 2c, how does the light intensity affect the number of the released electrons? In Activity 5a, how does the light intensity affect the magnitude of* *electron kinetic energy?"* All students (100%) correctly answer both questions.

After answering the questions, the module informed students that according to Albert Einsten, the energy carried by photons in the form of energy package in hf quantity. To investigate Einstein's statement, students doing a simulation using PhET. In the "*Options*" menu in PhET, "show photons" was chosen to see the incoming light in the form of photons and the "*control photon number instead of intensity*" was chosen to regulate the number of photons by adjusting the intensity of light, regulating sodium as metal, wavelength of 400 nm, changed the light intensity from 0% to 100%, then observed the incoming beam of light or photons as shown in Figure 8.

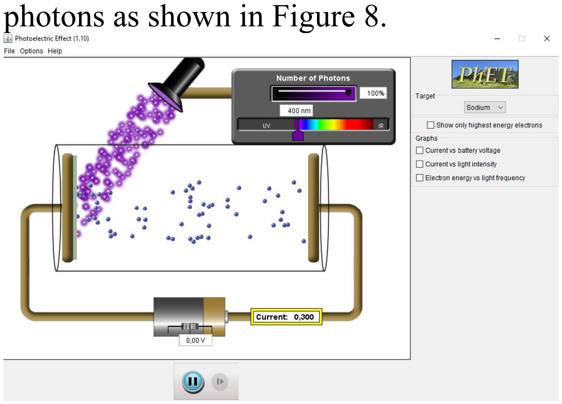

Figure 8. Display of PhET simulation results when photons come

After did the simulation, students answer the questions: *"When the light intensity is increased, how many are photons coming? Do they increase, decrease, or keep constant?, If the light intensity does not affect electron kinetic energy, does the number of incoming photons affect the magnitude of electron kinetic energy?"*. Based on observations, students were able to follow the steps in the module well and two students (50%) were able to answer the questions correctly, while the other two students answer incorrectly on the second question. This incorrectly occurred because students did not first read the information provided in the module, which it was informed in the module that if the light intensity does not affect number of the incoming photons though photons increased by the light intensity, the amount of the released electrons from a metal will increase but its kinetic energy is always fixed.

In Activity 7, it was informed that the light directed towards metal in the form of "energy packages" called photons. Thus, the nature of light in the Photoelectric Effect is quantized. Because the light energy received by electrons in the form of energy packets (or photons) with a magnitude of $h\ f$ which the magnitude of light intensity only increases the number of the released electrons but does not increase the electron kinetic energy.

Based on observations during Activity 7, all students (100%) were able to follow the module steps well, 50% of them answer the questions correctly. This shows that Activity 7 in the independent practicum module using PhET simulation effectively helps students to understand the nature of light in the Photoelectric Effect.

Analysis of Observation Results

During the independent practicum was going on, the observer filled out an observation sheet to record the running process of independent lab using the PhET simulation with the help of independent practicum module that had been created. To calculate the percentage of independent practicum continuity, the following formula was used:

$$N = \frac{n}{n_{max}} x\ 100\ \% \qquad (10)$$

where *n* is the number of activities carried out correctly, n_{max} is the total number of activities (7 activities). The results of observation can be seen in Table 5.

Table 7. Observation Results

No.	Activities	Students			
		A	B	C	D
1.	Students follow the module steps	100%	100%	100%	100%
2.	Students can find the Definition of Photoelectric Effect through PhET simulation	100%	100%	100%	100%
3.	Students can find Factors Affecting the Amount of Electrons released : a. The Effect of Voltage Towards of Released Electrons	100%	100%	100%	100%
	b. The Effect of Metal Types Towards of Released Electrons	100%	100%	100%	100%
	c. The Effect of Light Intensity Towards of the Released Electrons	100%	100%	100%	100%
	d. The Effect of the Light Wavelength Towards of the Released Electrons	100%	100%	100%	100%
	e. The Effect of Electric Current Towards of the Released Electrons	100%	0	0	0
4.	Students cand find Factors Affecting Threshold Wavelength (λ_0) :				
	a. The Effect of Metal Types on Threshold Wavelength (λ_0)	100%	100%	100%	100%
	b. The Effect of Light Intensity on Threshold Wavelength (λ_0)	100%	100%	100%	100%
	c. The Effect of Voltage on The Threshold Wavelength (λ_0)	100%	100%	100%	100%
5.	Students cand find Determining the Maximum Kinetic Energy of the Releasing Electrons:				
	a. Determining the Kinetic Energy of the Released Electrons	100%	100%	100%	100%
	b. Determining the Stop Potential (V_0)	100%	100%	100%	100%
6.	Students can find Factors Affecting Maximum Kinetic Energy :				
	a. The Effect of Light Intensity on Maximum Kinetic Energy of Electron	100%	100%	100%	100%
	b. The Effect of Light Wavelength on Maximum Kinetic Energy of Electron	100%	100%	100%	100%
	c. The Effect of Light Frequency on Maximum Kinetic Energy	100%	100%	100%	100%
7.	Students can understand The Relationship of Electron Kinetic Energy and Incoming Light Energy and Work Function	100%	100%	100%	100%

8.	Students can investigate The Nature of the Light of Photoelectric Effect	100%	100%	0	0
9.	Students not ask the observer more than 8 times about the contents and clarity of the module	100%	100%	100%	100%
Average		**100%**	**94,44%**	**88,89%**	**88,89%**
Category		**Very Good**	**Very Good**	**VVery Good**	**Very Good**

Table 7 shows that all student was able to follow the steps in the module, answer all questions correctly, and did not ask any questions more than 8 times. Based on observations, 3 students (75%) were not able to conclude correctly about the effect of electric current on the number of the released electrons in Activity 2e.

Overall, all students (100%) were able to follow the module steps properly and each student was able to answer questions correctly in the module at ≥70% from 100%. With this result, it can be said that the practicum module **effective** guides students to simulate photoelectric effects independently.

Analysis of Evaluation Results

After the independent practice using the PhET simulation was completed, students were given evaluation questions to find out their understanding of Photoelectric Effect. Formula in equation (10) can be used to calculate the obtained evaluation value. The evaluation results can be seen in Table 8.

Table 8. Evaluation Results

No	Student	Result	Category
1	A	90	Very Good
2	B	90	Very Good
3	C	95	Very Good
4	D	90	Very Good
Average		**91.25**	**Very Good**

Table 6 shows that all students (100%) scored ≥70 out of 100 with an average score of 91.25 overall. This shows that the independent practicum module about Photoelectric Effect using PhET simulation effectively helps students to understand about Photoelectric Effect.

Analysis of Questionnaire Results

After students finished working on the evaluation questions, students were given questionnaire sheets to see their assessment of the practicum and modules. The results of the evaluation questions and questionnaire will be analysis with score based on conditions Table 1, then calculate the percentage with the following conditions on Table 2.

Table 9. Questionnaire Results

No.	Indicator	Respondents				Average	Category
		A	B	C	D		
1.	The assessment of fonts, images, colors	100	75	100	75	**87.50**	Very Good
2.	The use of sentences provides good information	100	75	75	75	**81.25**	Very Good
3.	The use of modules is simple and easy to understand	100	75	75	75	**81.25**	Very Good
4.	The guide in the module is easy to understand	100	100	100	75	**93.75**	Very Good
5.	The use of modules can help in operating the PhET "Photoelectric Effect" simulation	100	75	100	100	**93.75**	Very Good
6.	Enthusiastic learning to use an independent practicum module using a PhET simulation	100	100	75	75	**87.50**	Very Good
7.	Effectiveness of the independent practicum module for respondent understanding	100	75	75	75	**81.25**	Very Good

The greater the scale chosen, the greater positive response were given by students. The target of this study is that ≥ 70% of students gave a positive response to the questionnaire. From the results of this questionnaire it can be concluded that all students (100%) were enthusiastic about doing independent practicum using this PhET simulation of Photoelectric Effect. Students assumed that learning with PhET simulation effectively helped them to understand about Photoelectric Effect. Students gave assessments that the letters and colors of images in the module were easy to read, the module provided clear practical information and instructions, the sentences used in the module were simple and easy to understand. The steps and explanations of this module were also effective in helping students understand the material of Photoelectric Effect.

Thus, the independent practicum module using PhET simulation can be said to be **effective** in providing guidance for students to explore the material of Photoelectric Effect independently. So, this module can be used as a structured task and independent learning about Photoelectric Effect.

Interview Results

After filling out the questionnaire, interviews were conducted with students as respondents from this study. Students claimed that conclusion could not be made about the effect of electrical current on the number of the released electrons in Activity 2e. Students also had difficulty in determining the threshold wavelength (λ_0) in Activity 3a because it requires precision in changing wavelength intervals until electrons no longer come out of a metal plate. In addition, students gave suggestions that the sentences used in the module should be simpler.

CONCLUSION

The design of independent practicum module that has been made using the PhET simulation for learning the Photoelectric Effect is **effective** in helping students explore about Photoelectric Effects independently. This practicum module can also be used as a structured assignment and independent learning. However, the independent practicum module of the Photoelectric Effect has not succeeded in making students determine the effect of electric current on the number of the released electrons as shown in Activity 2e. Therefore, it is suggested that the next studies can develop the design of independent practicum module about Photoelectric Effects using PhET simulations or other learning media, especially on the effect of electric current on the number of the released electrons, enrich the variety of independent practicum modules on other physics material for students, and increase the number of respondents so that the effectiveness of the module will be higher. For the further research, it can be developed for HOTS learning

REFERENCES

A. Beiser. 1983. Konsep Fisika Modern (Terjemahan). Jakarta. Erlangga

Dinavalentine, M., Sudjito, D. N., Noviandini, D. (2016). Desain Modul Praktikum Mandiri tentang Pembiasan Cahaya Menggunakan Simulasi PhET "*Bending Light*" untuk Mahasiswa. *Prosiding Seminar Nasional Quantum 2016,* pp. 91-104.

Hapsara, S. A., Sudjito, D. N., Noviandini, D. (2017). PhET (*Physics Education*

Technology) Virtual Laboratory as Physics Learning Media about Factors that Influence the Number of Emitted Electrons in Photoelectric Effect. *4th ICRIEMS Proceedings.*

Indriyani, Lusi. (2016). Pengaruh Penggunaan Simulasi PhET dengan Model Problem Solving terhadap Minat Belajar Siswa pada Pembelajaran tentang Hukum Boyle dan Gay Lussac di Kelas XI IPA SMA Negeri 1 Prambanan dan SMA Negeri 2 Klaten. *Yogyakarta: Fakultas Kepengajaran dan Ilmu Pendidikan Universitas Sanata Dharma.*

Musawi, Al., Ambusaidi., S, Al-Balushi., K, Al-Balushi. (2015). Effectiveness of E-Lab use in Science Teaching at the Onami Schools. *The Turkish Online Journal of Educational Technology*, 14(01).

Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R. (2006). PhET: Interactive Simulations for Teaching and Learning Physics. *The Physics Teacher*, 44, 18-23. https://doi.org/10.1119/1.2150754

Podolefsky, N. S., Perkins, K. K., & Adams, W. K. (2010). Factors Promoting Engaged Exploration with Computer Simulations. *Physical Review Special Topics - Physics Education Research,* 6 (020117).

Prihatiningtyas, S., Prastowo, T., Jatmiko, B., (2013). Implementasikan Simulasi PhET untuk Mengajar Keterampilan Psikomotorik pada Pokok Bahasan Alat Optik. *Jurnal Pendidikan IPA Indonesia*. 2(1): 18-22.

Pujiyono, P., Sudjito, D. N., Sudarmi, M. (2016). Desain Pembelajaran Dengan Menggunakan Media Simulasi PHET (Physics Education and Technology) Pada Materi Medan Listrik. *UPEJ Unnes Physics Education Journal*, *5*(1).

Riduwan. (2011). *Skala Pengukuran Variabel-Variabel Penelitian*. Bandung: Alfabeta.

Setiawan, A., Suyatna, A., Abdurahhman, (2016). Pengembangan Simulasi Praktikum Efek Fotolistrik dengan Pendekatan Inkuiri. *Jurnal Pembelajaran Fisika,* 4(1): 48.

Yuafi M.E.D, & Endryansyah. (2015). Pengaruh Penerapan Media Pembelajaran *PhET Simulation* terhadap hasil belajar siswa kelas X TITL pada standar kompetensi mengaplikasikan rangkaian listrik di SMKN 7 Surabaya. *Jurnal Pendidikan Teknik Elekro*. 4(1): 407-41.