Using computer simulation to improve high order thinking skills of physics teacher candidate students in Compton effect

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Abstract. The process of learning and teaching in Physics is often confronted with abstract concepts. It makes difficulty for students to understand and teachers to teach the concept. One of the materials that has an abstract concept is Compton Effect. The purpose of this research is to evaluate computer simulation model on Compton Effect material which is used to improve high thinking ability of Physics teacher candidate students. This research is a case study. The subject is students at physics educations who have attended Modern Physics lectures. Data were obtained through essay test for measuring students' high-order thinking skills and quisioners for measuring students’ responses. The results obtained indicate that computer simulation model can be used to improve students’ high order thinking skill and can be used to improve students’ responses. With this result it is suggested that the audiences use the simulation media in learning

1. Introduction

One of the important problems in Physics learning is the low quality of learning at various levels of education. The quality of the process and the results of physics learning is determined by some factors one of the availability of laboratory facilities. Laboratory activities are important to be implemented in physics learning, because through laboratory activities aspects of products, processes, and attitudes of learners can be further developed. Physical learning based on laboratory activities can improve the mastery of concepts, generic science skills, and high-order thinking skills of learners. These skills are very important to equip learners in solving various problems faced in society.

Higher-order thinking becomes one of the qualities teachers must have to face the challenges of the 21st century [1]. Although there has been a lot of research on the thinking ability of high-level teachers (Zohar, 2004, Mîri, David & Uri, 2007; Dresner, et al, 2013; Ramos, Dolipas, & Villamor, 2013) the fact that prospective teachers cannot explain clearly thinking their high level [2]. This becomes an important foundation for researchers to find out the most appropriate way to improve the current high-level thinking skills of prospective teachers, especially physics teachers, because physics can be categorized as high-level thinking that is difficult to understand and teach discipline [3].
The thinking ability of prospective teachers in understanding the material of physics can influence students' understanding of the material of physics [4]. Students will not be able to deal with issues that demand high-level thinking and problem solving if students are not trained in using their high-level thinking and thinking skills [5].

The selection of this topic is based on the special characters in Compton's own theory of effects, including the high difficulty level and the number of possible experiments so that the developed model can contribute more to the acquisition of the thinking level of physics teacher candidates. In addition, Compton's theory of effects shows that it belongs to the abstract concept. So it needs to be visualized. Abstract concept on Compton effect material cause student have difficulty to understand this concept well. This resulted in low student learning outcomes in the modern physics course in general.

In 1919, Einstein concluded that photons with energy E move in a single direction and carry momentum $E/c = hf/c$. In 1923, Arthur Holly Compton (1892-1962) and Peter Debye (1884-1966) independently proceeded with the idea of Einstein. Before 1992, Compton and his colleagues managed to gather evidence suggesting that the wave-wave theory for light had failed to explain the spread of X-rays to electrons. According to the classical theory, electromagnetic waves with frequencies $\omega$ coming to electrons will have two factors (1) the radiation pressure will cause the electrons to accelerate in the direction of propagation or wave propagation, and (2) the electric field from the oscillation of the dating radiation will cause the electron to be isolated at the frequency $f'$, where $f'$ is the frequency within the framework of the moving electrons. Frequency $f'$ is different from the frequency $f_0$ of the dating radiation due to the elopment of the Doppler. Each electron, will first absorb the radiation when the particles move and then radiate back the radiation when the particles begin to move, thus there have been two Doppler shifts in the radiation frequency.

Other electrons will move at different speeds after the interaction, depending on the amount of energy absorbed from the electromagnetic waves, the frequency of the waves scattered at a certain angle from the coming radiation will show the value of the Doppler shift distribution. In contrast to this prediction, Compton's experiments show that, at a certain angle, only one radiation frequency can be observed. Compton and his coworkers realized that they could explain this experiment by treating photons not as waves but as particles with $hf$ energy and $hf/c$ momentum, and assuming that both the energy and momentum of the isolated photoelectron students were eternal. Compton uses a particle model for something called a wave, and is called the Compton effect [6].

Alternative solutions offered include through the utilization of computer technology. Finkelstein says that computers can be used to support the implementation of physics lab [7]. Not only can it be used to collect data, present, and process data, computers can also be used to modify experiments and display complete experiments in virtual form. Garrison states that technology can be adapted into an active learning approach [8]. It needs to be a combination of face to face with online learning. Some things to consider between possible approaches, strategies, techniques, and existing tools. One form of utilization of computer technology on Compton effect material is the development of practical simulations. Simulation is defined as a training method that displays something in an artificial form similar to the actual state. Simulation can be done to identify factors that influence in a system, or prediction of system behavior by taking into account the related factors. Thus, a formula or rules that apply in a system is absolutely necessary for forecasting (prediction / forecasting) in the simulation can run. By doing forecasting, it is expected to understand how factors affect the output of a system; So that proper system control can be done, in order to obtain the desired output [9]. With computer technology the theory of compton effect is realized in the computer program by using software that is easy to learn that is experiment simulation.

In learning that uses the simulation method, students are fostered ability related to interaction skills and communicate in groups. In addition, in the simulation method students are invited to be able to play the role of some behaviors that are considered in accordance with the purpose of learning. The process of teaching and learning with the lab according to Sagala is a learning process where students are given the opportunity to experience themselves, observe the process, observe an object, analyze, prove, and draw its own conclusions about an object, state, or process something[9]. This opinion is
supported by Aqib which reveals that practical activities using certain tools can train students' skills in using the tools they have been given and the results they achieve [10].

Gunawan found that interactive multimedia models in basic physics learning can improve generic science skills of prospective teacher students, where indirect observation indicators experienced the highest increase [11]. McKagan found that the use of computer simulations on quantum mechanical materials can improve student learning outcomes and activities in the classroom [12]. The use of computer simulations helps students overcome their learning difficulties in this material. Gunawan finds that the use of virtual laboratory of modern physics can also improve the mastery of student candidates' concepts, especially on the quantum theory of electromagnetic radiation and matter [13].

Based on the above description, in this study has developed a learning media in the form of practical simulation as an alternative solution to limited laboratory facilities and experimental difficulties in the theory of Compton effect abstract. This virtual laboratory model is expected to improve generic science skills of prospective teachers. In this article we will describe the description of the Compton practice simulation of the Compton effect that has been developed and the effect of the use of Compton effect experiment simulation on the improvement of high thinking ability of physics teacher candidate students.

2. Research Methods
This research is a development research with Recursive Reflective Design and Development (R2D2) design developed by Willis [14]. This design is used because it is reflective, recursive, collaborative and evolving so as to give researchers and stakeholders the opportunity to develop the learning product according to the needs continuously until found the product that is considered the most appropriate, effective and efficient.

This study was conducted on 35 physics education students of UNS 2016/2017 academic year selected randomly. Students are given 15 points about high ability thinking test that is in the form of description problem. Problem compiled based on the indicator of high-order thinking ability is the ability to analyze (C4), the ability to synthesize (C5), the ability to create (C6). A limited trial was conducted by applying learning media in the form of a experiment simulation to determine the level of students' ability in high-level thinking. The method used is pre test post test group by looking at comparison of mean value of each indicator in high level thinking. To see the effectiveness of learning outcomes then performed a normalized Gain calculation with the equation:

\[ g = \frac{S_f - S_i}{100 - S_i} \]

3. Results And Discussion
The results of the analysis of high-thinking ability of prospective teachers can be increased by utilizing the practical simulation media. This is shown in the comparison of pretest and posttest's average grades of 35 prospective teachers is 40.08 and 68.4. The average analysis of the value of 35 prospective teachers using the equation:

\[ \bar{x} = \frac{\sum n}{N} \]

Information : \( \bar{x} \) = average value
\[ \sum n = \text{total skor} \]
\[ N = \text{number of prospective teacher} \]

The following is the average value of the teacher's high-level thinking ability for each indicator of high-level thinking ability.
Table 1. The result of calculating the average value of prospective teachers on each indicator of high-level thinking ability.

| No. | HOTS Indicators                      | Question Number            | Average | Pretest | Posttest |
|-----|--------------------------------------|----------------------------|---------|---------|----------|
| 1   | The ability to analyze (C4)          | 2, 3, 7, 9, 14 dan 15      |         | 37.5    | 60       |
| 2   | The ability to synthesize (C5)       | 1, 4, 6, 8, 12, dan 13     |         | 42.75   | 70       |
| 3   | The ability to create (C6)           | 5, 10, dan 11              |         | 40      | 75.25    |

The average value of pretest on the matter of C4, C5 and C6 is almost the same. The value indicates that the high order thinking skills before the treatment. The percentage of pre test score for the C6 question is the highest among other question. This is because the problem of C6 tends to be easier but it can also be done even though it has not received the previous material.

The experiment simulation used using adobe flash professional cs6. Adobe Flash is a very popular program for creating vector-based 2D animations. The latest application program from Adobe Flash is Adobe Flash Professional CS6, this application is the previous version of Adobe Flash Professional CS 5.5. The description of the device developed with a experiment simulation model is as shown in Figure 1.

![Figure 1](image.png)

Figure 1. The design of instructional media using a experiment simulation

The learning media consist of 6 pages. The first page shows the title of a experiment simulation Compton effect. Then on the second page there is the introduction of the material, on the third page in the form of the steps of using the simulation media, then the fourth page displays the compact practice experiment simulation media which shows virtual how to experiment the Compton effect by determining the angle the scattering of photons and the enormous energies of x rays fired at the electrons thereby scattering and generating larger scattered lambda values compared with the lambda before scattering. In addition, on the next page, the fifth page is a mathematical process that shows the scattering angle values of the electrons. So student can better understand how to get the scattered electrons angle value. The last page shows the glossary used in Compton effect simulation media.

HOTS prospective teachers can be measured through the three highest cognitive abilities in taxonomy bloom, among others, 1) analyze (C4), 2) evaluate (C5), 3) create (C6) [15]. Assessing high-level skills can improve the grades or achievements of prospective teachers [16]. The following is an explanation of descriptive analysis of candidate answers to the teacher's test based on indicators of high-ability thinking.
Indicator 1: The ability to analyze (C4)

Analyzing means breaking down information into sections, determining how parts are related to each other. There are 6 items on the first indicator of question number 2, 3, 7, 9, 14 and 15. Indicator about number 3 is analyzing the particle nature of electromagnetic radiation. Here are some examples of answers that show different analytical skills of 2 students.

Figure 2. The Student A’s Answer Number 3

In the first answer, student A compares three initial experiments that lead to quantum theory and explain the results obtained through the experiment. And based on the interview results show that the answers and interview results accordingly.

Figure 3. The Student B’s Answer Number 3

Student B also gives the correct answer, just as with student A but student B does not provide the desired explanation. Similarly, the results of the interviews obtained, student B not so understand about further discussion of experiments that prove the nature of light dualism.

Indicator 2: The ability to synthesize (C5)

Synthesis means to justify a statement or plihan with a certain reason. There are 6 items on the first indicator of question number 1, 4, 6, 8, 12, and 13. Indicator about number 1 is selecting the most appropriate statement about the Compton effect experiment. Here are some examples of answers that show different analytical skills of 2 students.
1. The exact statement is:
   a. On the Compton effect proven that photons and electrons correspond to the law of conservation of momentum
   b. The kinetic energy of the outgoing (scattering) electrons depend on the wavelength of the light for which reason the kinetic energy is proportional to the wavelength
   c. The frequency of the photons before the collision is greater than the frequency of the photons after the collision of the reason is frequency is proportional to Energy

**Figure 4. The Student A’s Answer Number 1**

In the answer above, student A’s answer indicates that the selected statement along with the reason is not yet appropriate. Based on the results of the interview it is because students answer based on the ongoing material and forget the previous material related to Compton effect material.

1. Correct statement:
   c. The frequency of the photons before the collision is greater than the frequency of the photons after the collision of the reason is frequency is proportional to Energy

**Figure 5. The Student B’s Answer Number 1**

Whereas in answer student B shows that the statement and the reasons used are appropriate. This is because students are already familiar with Compton effect material.

**Indicator 3: The ability to create (C6)**

Creating means to create or develop new products, theories, or points of view based on learning. There are 3 items on the first indicator of question number 5, 10, and 11. Indicator about number 5 is formulate the Compton effect equation. Here are some examples of answers that show different analytical skills of 2 students.
Figure 6. The Student A’s Answer Number 5

A student’s answer indicates that his ability to formulate the Compton effect equation is correct. Students explains the coherence of the conservation equation of energy and momentum used, accompanied by an explanation of the treatment of each equation obtained. From the result of the interview show that student A is well-informed about the relationship between conservation of momentum and energy conservation law on the invention of Compton effect formulation.
While student B’s answer indicates that the written equation is not wrong, but student B only writes the equation of conservation of momentum and the law of conservation of energy and then comes the equation of Compton effect without any way used to get the formulation. And based on interview result, student B only know that there is equation of Compton effect with both conservation law of energy without knowing process.

The considerable difference is far enough indicates that there are differences in the high order thinking skills of students before and after Compton effect learning by using a practical simulation media.

**Figure 7.** The Student B’s Answer Number 5
By utilizing the simulated media students become accustomed to thinking systematically so that in doing the student’s questions also become easier and get better results. The PBL model also trains students to be more skilled in solving and finding solutions to problems. To solve a problem requires the high order thinking skill because students must analyze various information to find the right solution.

The result shows that using computer simulation proved superior to improve high order thinking skills of physics teacher candidate students in Compton effect. Students have dared to make decisions that are deemed appropriate based on the evidence they have obtained. This evidence is based on the results of the discussions that they follow in a sustainable manner using the Compton effect simulations. The lowest average score of students is found on the create indicators. In this activity the students seek solutions about new problems encountered by using the concepts already obtained and the completeness of supporting evidence. In this indicator students solve the problem through quiz activity. In order for students to interpret a problem it requires accuracy, clarity, consistency, and jelly in determining the variables. The average comparison of the students' high-order thinking skill based on table 1 obtained the total pretest score is 40 and after implementing the learning process using the experiment simulation the posttest score is 68.3. To see the effectiveness of the product obtained the calculation of the normalized gain value of 0.5 indicates a moderate value. The increase in the average student is obtained because of the intensity of students interact either directly in the classroom through learning media in the form of a experiment simulation. In addition, by using the practical simulation problems presented can also be visualized by students.

Curiosity of students become higher because of the difficulty of the material being studied. High curiosity and high motivation, encourage students to use all their thinking skills to get the perfect solution. In other words, using this experiment simulation can train students to improve high order thinking skills.

4. Conclusions
Based on the results and discussion learning media tools developed through experiment simulations can improve students' higher-order thinking skills. It is proven through validation test result is 3.29 (valid enough). The result of the average score of 35 students in high-order thinking skills after the process using learning media of experiment simulation was 68.5 with the normalized gain value was 0.5. The value is included in the category is. The average value each indicators for pretest and posttest are 37.5 and 60 for ability of analyze (C4), 42.75 and 70 for ability of synthesize (C5), 40 and 75.25 for ability of create. Seen that the considerable difference is far enough indicates that there are differences in the high order thinking skills of students before and after Compton effect learning by using a practical simulation media. By using the practical simulation problems presented can also be visualized by students and can train students to improve high order thinking skills.

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