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VIRTUAL SIMULATION EXPERIMENT OF POTENTIAL ENERGY OF SPRINGS PHET USING HOT-LAB MODEL: IMPLICATIONS FOR EDUCATION

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ABSTRACT

This study explores how effective the Higher Order Thinking Laboratory (HOT-Lab) model is in physics learning, especially on the concept of spring potential energy through virtual PhET simulation. The HOT-Lab model is designed to improve students' critical, creative, and analytical thinking skills and their ability to solve complex problems. This study tries to compare the variation of force and spring constant in a virtual experiment to see its effect on the spring potential energy. The results show that the applied force, spring constant, and potential energy stored in the spring are closely related to each other. Increasing the force or spring constant directly increases the spring potential energy. Virtual PhET simulation has been shown to be a useful tool in visualizing abstract concepts, facilitating variable analysis, and improving students' higher order thinking skills. The results of this study indicate that HOT-Lab has great potential as an innovative method in physics laboratory learning that can develop students' scientific skills in a more in-depth and contextual way.

Keywords :*Laboratory; HOT-Lab; Virtual Lab; Education; Spring Potential Energy.*

I. INTRODUCTION

Education is undergoing continuous evolution, requiring improvements from time to time, with a focus not only on understanding the material, but also on developing students' skills. [1]. The development of scientific thinking skills is a major focus in the world of education, especially in efforts to improve the progress of science and technology. [2]. Especially in 21st century education, learning must be able to align critical skills, creativity, effective communication, cooperation, and understanding of digital technology into the student learning process, so that they can become a generation that is ready to face various challenges that will come. [3]. According to Bao et al. (2022) and Vo & Csapó (2022), scientific thinking skills are an important key in solving complex problems and pioneering innovation. [4]. The education sector has begun to respond by developing various learning methods aimed at improving scientific thinking skills, from elementary to university level. [5]. Therefore, in the era of ever-evolving education, it is important for educational institutions to continue to update teaching methods to improve learning effectiveness. One method that has received attention is the use of High-Level Thinking Laboratory (HOT Lab) in physics learning. [6]. [7]mentioned that practical activities have an important role in the science education curriculum, especially physics. However, evidence related to the development of scientific thinking skills in laboratory activities is still minimal. Physics laboratories are often only focused on the development of procedural practical skills and proof of concepts. [8]. This problem is a concern along with the rapid development of science and technology, science education must be able to provide the skills and knowledge needed so that students can compete and contribute effectively in a world that is constantly changing. [9].

The use of laboratories has an undeniable significance in the structure of the science education curriculum at the post-secondary level, especially in disciplines such as chemistry, physics, and biology. Experimental and hands-on activities in the laboratory are considered to be a very efficient strategy for promoting understanding of science concepts, enhancing practical skills, and providing students with hands-on experience in the scientific process. [10]. . The role and implications of the laboratory are as a place to conduct research and development in physics learning. [11]The use of a practical model has a very big influence on improving students' critical and creative thinking skills and problem-solving abilities. In this case, HOT-Lab is recognized as being an innovative approach. [12]. However, many college labs still use a traditional or “cookbook” approach, where students follow a predetermined procedure to achieve a desired outcome. This traditional method often involves structured steps and known outcomes, which limits the exploration and critical thinking aspects of scientific experiments. [13].

Therefore, the high-level thinking laboratory (HOT-Lab) model emerged as a new alternative in developing students' scientific thinking skills, including creative thinking skills. [14]. HOT-Lab is a combination of the creative problem solving learning model and the problem solving laboratory model. [15]. Creative thinking skills play a significant role for students because they enable them to hone their problem-solving skills, find innovative ideas, and think originally. [16]. This article aims to determine the effectiveness of using the HOT-Lab practicum model in developing students' creative thinking skills in physics learning.

Specifically, this study examines the topic of spring potential energy, an important concept in mechanical physics that is often difficult to understand intuitively without experimental practice. By using the HOT-Lab (Higher Order Thinking Skill Laboratory) model, PhET simulation experiments are expected to provide an experience similar to a physical laboratory. This HOT-Lab model allows users to develop analytical skills, hypothesis posing, problem solving, and data analysis, which are usually obtained from conventional laboratory activities.

This study aims to analyze the implications of using PhET virtual simulation on the material of spring potential energy in physics education. The research method begins with the author himself experiencing HOT-Lab practicum activities directly, starting from understanding concepts, submitting problems, to data processing and making conclusions. Furthermore, a literacy study was conducted to compare this experience with various relevant literature. The results of the study are expected to provide insight into the effectiveness of PhET simulation as a learning tool in a virtual laboratory and its potential in improving students' understanding of physics concepts.

II. METHOD

The research method used in this study is a combination of experimental methods with systematic literature review or library studies. The experimental method is used with the aim of observing, measuring, and analyzing the effects of PhET virtual simulations on students' understanding of the concept of spring potential energy in the context of an educational laboratory. [17]. The experimental method was chosen because it allows researchers to test cause-and-effect relationships directly through the manipulation of certain variables and observation of their impact. [18]. This method is relevant because the PhET virtual simulation is designed to replace or complement physical laboratories with experimental experiences that can provide direct insight into the effectiveness of this method in learning physics concepts. [19].

The experimental method was chosen because of its advantage in ensuring strict control over variables, which allows the study to provide more accurate and reliable results. [20]. In the context of this study, the PhET virtual simulation allows researchers to compare the effects of traditional laboratory experiences with the HOT-Lab model in understanding the potential energy of springs. With the experimental method, researchers can directly assess the effectiveness of this simulation in building students' understanding and analytical skills. [21]. This experimental method was also used because it could allow researchers to directly assess the impact of simulation on students' understanding and to explore the potential of the HOT-Lab model in developing students' laboratory skills effectively. [22].

The experimental method was conducted using PhET Virtual Lab Simulations. Data were obtained through the Hooke's Law PhET virtual laboratory. The Phet virtual laboratory was chosen because it provides easy control over the variables involved in the study. The data obtained were then processed and presented quantitatively.

The SLR method is used because this research also contains studies in libraries to collect and evaluate related research on a particular discussion focus. [23]. This research uses descriptive explanation. According to [24], there are four stages in making a literature review, namely: 1) choosing a topic to be reviewed, 2) tracking and selecting suitable or relevant articles, 3) conducting literature analysis and synthesis, and 4) organizing the writing of the review. The articles used as references are articles that have been indexed by Scopus, SINTA, and Google Scholar in the last 5 years so that they have convincing credibility and validity. This study uses a descriptive analysis method [25].

III. RESULTS AND DISCUSSION

Background and Purpose of Using HOT-Lab

In the world of education, especially in physics learning, the success of the teaching and learning process is often measured by how well students can understand physics concepts and apply them in real-life contexts. [26]. However, conventional physics practicums often only focus on verification and procedural aspects, without providing enough space for students to develop creative and critical thinking skills. [27]. This creates a need for more innovative learning approaches, such as HOT-Lab. [14].

HOT-Lab, which stands for Higher Order Thinking Laboratory, is a learning approach that combines creative problem-solving models with physics practical experiences. [28]. The main goal of HOT-Lab is to overcome the limitations of traditional physics labs by providing students with opportunities to think critically, creatively, and solve more complex problems. [29].

Implementation of HOT-Lab in Physics Practicum

In his article [30]mentioned that HOT-Lab can be implemented through two main approaches: HOT Real Laboratory and HOT Virtual Laboratory. HOT Real Laboratory is a physics practicum conducted directly in the laboratory, while HOT Virtual Laboratory uses computer simulation to simulate the practicum experience.

According to [31], in HOT Real Laboratory, students are given real challenges that require problem solving and creative exploration. They are given the opportunity to plan and carry out their own experiments, while developing practical skills such as the use of measuring instruments and data analysis. In addition, in the research conducted by [32].

Technology has played a vital role in physics laboratory learning, especially in overcoming conventional learning barriers and providing students with access to a variety of practical activities. [33]. [34]using HOT Virtual Laboratory which utilizes computer simulation technology to create a virtual laboratory environment that allows students to conduct experiments in a safe and controlled environment. a virtual laboratory is a set of interactive laboratory instruments, using multimedia media, which are run through a computer, giving users the experience as if they were in a real physical laboratory. [35]. Virtual laboratories bring significant benefits in physics learning with accurate and easily accessible simulations that allow students to visualize difficult-to-understand physics concepts directly in everyday life. [36]. Implementing virtual lab-based practical activities can also stimulate student participation in class, so that this innovation can improve students' understanding of concepts. [37]. HOT Lab provides greater flexibility for students to experiment with physics concepts without the limitations of laboratory tools or materials. [38].

Meanwhile, based on research conducted by [39]combining both methods between HOT Real Laboratory and HOT Virtual Laboratory into HOTVRL and it is considered that HOTRVL (Higher Order Thinking Real and Virtual Laboratory) can significantly improve 21st century skills, such as critical and creative thinking, and communication skills. Therefore, HOTRVL can be effectively used in the context of physics learning.

Implementation of HOT-Lab Learning Model in Physics Practical on Spring Potential Energy Material Based on PhET Virtual Simulations

This physics practicum was conducted using an experimental method to study the elastic properties of springs (Hooke's law), especially the effect of the spring constant on the increase in the length of the spring when it is stretched. Hooke's law states that the force acting on a spring is directly proportional to the increase in the length of the spring but inversely proportional to its spring constant. [40]. This law is formulated as:

$$F = k.\Delta x \quad (1)$$

with:

F= Force applied (N)

K= Spring constant (N/m)

Δx= Change in spring length (m) [41]

In relation to Hooke's Law, spring potential energy is a type of mechanical energy stored in an elastic object when it experiences a change in shape, such as elongation or shortening. A spring is one example of an elastic object that can store potential energy when given an external force, according to Hooke's law in physics, which states that the force acting on a spring is proportional to the change in its length, so that spring potential energy is closely related to the concept of work done by or on the spring.

The potential energy of a spring arises due to deformation of the spring, either in the form of elongation or shortening. The magnitude of the potential energy of a spring (W) can be calculated using the following equation:

$$E_P\ Pegas = \frac{1}{2}kx^2$$

With:
E_P= Potential energy of spring (Joule)
k= Spring constant (N/m)
x= Change in spring length (m)
For our efforts we can obtain it by:

$$\frac{1}{2}kx^2 = E_P$$

$$\frac{1}{2}kx(x) = E_p$$

$$\frac{1}{2}Fx = E_p$$

$$W = E_P$$

$$\frac{1}{2}Fx = \frac{1}{2}kx^2$$

It can be seen in the equation above that the work and the potential energy of the spring are related. In addition to both having the same unit, namely Joule, the equality in the equation above also shows the pattern of the relationship between the force applied and the value of the potential energy of the spring itself. Based on this, this experiment was designed by varying F or the force applied and the spring constant (k) to find out how these two things affect the potential energy of the spring. The data obtained from the results of this experiment can be seen in the table below.

Table 1. Observation Table of Variation of Changes in Spring Length

No	*F(N)*	*Δx (m)*	*Ep Spring (J)*	*K (N/m)*
1	25.0	0.25	3.10	100
2	50.0	0.50	12.5	100
3	75.0	0.75	28.1	100
4	100	1.00	50.0	100

(Source: Ref [1])

Table 2. Spring Constant Variation Observation Table

No	*F(N)*	*Δx (m)*	*Ep Spring (J)*	*K (N/m)*
1	50.0	0.50	12.5	100
2	62.5	0.50	15.6	125
3	75.0	0.50	18.8	150
4	87.5	0.50	21.9	175

(Source: Ref [2])

The data in table 1 shows that the value of the applied force in Newton can significantly affect the potential energy of the spring. The force applied also has a direct effect on the change in the length of the spring. Δx.In the first experiment, a spring with a spring stiffness constant of 100 N/m was given a force of 25.0N and deformed by 0.25m. The potential energy contained in the spring in the first experiment was 3.1 Joules. In the second experiment, the spring was given a force of 50.0N and deformed by 0.50m. The potential energy contained in the spring increased to 12.5 J. In the third experiment, the spring was given a force of 75.0N and deformed by 0.75m. The potential energy contained in the spring increased again to 28.1J. In the fourth experiment, the spring was given a force of 100N and deformed by 1.00m. Its potential energy increased to 50.0J. It can be seen that the relationship between the force applied is directly proportional to the potential energy of the spring. The greater the value of the force applied to the spring, the potential energy of the spring increases exponentially.

In the second experimental scheme, the variation used is the spring constant. In the first experiment, the given spring constant is 100N/m. At a specified deformation of 0.50m, the spring potential energy contained in the spring is 12.5J. In the second experiment, the given spring constant is 125N/m and the spring potential energy increases to 15.6J. In the third experiment, the given spring constant is 150N/m and the spring potential energy increases to 18.8J. In the last experiment, the spring potential energy increases again to 21.9J after being given a spring constant of 175N/m. All experiments in this scheme use the specified deformation. It can be seen again that the spring constant has a directly proportional relationship with the spring potential energy. The greater the value of the spring constant, the higher the spring potential energy will be and the force required to cause the spring to deform at the same level will also increase and directly affect the effort required.

The virtual lab experiment experience using the HOT-Lab model is considered to have the potential to be used in the physics learning process in the laboratory. Experiments on the material of spring potential energy can provide students with a contextual understanding of spring potential energy and its implications for everyday life. The HOT-Lab model used has the potential to improve students' high-level thinking skills.

IV. CONCLUSION

This study highlights the effectiveness of the HOT-Lab model in physics learning, especially on the concept of spring potential energy, through the use of virtual simulation. Through experiments involving variations in force and spring constant, the results show that the relationship between force, spring constant, and spring potential energy is very significant. The greater the force applied to the spring, the potential energy stored in it will increase exponentially. Likewise, an increase in the spring constant results in an increase in potential energy, which means the spring will store more energy and require more force for the same deformation.

The application of the HOT-Lab model through PhET simulation in this experiment provides great benefits in building a deep understanding of abstract physics concepts. Students can directly observe the relationship between variables, analyze data, and solve problems in a creative and critical way. This experience shows that the HOT-Lab model is able to enrich the learning process by improving students' higher-order thinking skills and fostering their ability to deal with complex problems. The implementation of HOT-Lab in physics education offers great potential as an innovative solution for laboratory practical learning, supporting the development of essential 21st-century skills for students.

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