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Discovery Learning-Based Virtual Laboratory in Physics Education as an Effort to Enhance Students' Scientific Attitudes

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Abstract: This research aims to evaluate the effectiveness of using discovery-based virtual laboratories in enhancing students' scientific attitudes towards the topic of the photoelectric effect. The method employed a quasi-experimental design involving 12th-grade students at SMAN 2 Yogyakarta. The research design employed is pretest-posttest, nonequivalent multiple-group design. Subject selection was conducted through purposive sampling, resulting in experimental and control classes. The research subjects were from classes 12 MIPA 4 and 12 MIPA 5. Data were collected through questionnaires and observations of scientific attitudes. Observations during the learning process were conducted by three observers. The results of the study showed an improvement in the understanding of physics concepts and the development of scientific attitudes in the experimental group, with an average score of 89.36. The improvement in the experimental group was higher than that in the control group. These findings indicate that virtual laboratories based on discovery learning are effective in enhancing students' scientific attitudes. This finding highlights the potential of virtual laboratories in fostering scientific attitudes and assisting students in understanding modern physics, thereby stimulating their interest in the subject. The positive implications for physics education indicate that this approach can address students' challenges in learning physics conventionally.

Keywords: Discovery learning; Photoelectric effect; Physics education; Students' scientific attitudes; Virtual laboratory

Introduction

The photoelectric effect is a significant phenomenon in physics that has found various important applications in modern technology. One of its primary applications is in photovoltaics, where the photoelectric effect is utilized to convert sunlight into electrical energy. Additionally, the photoelectric effect is also associated with light detection technology, such as photodiodes, and is used in various optical devices, including digital cameras and optical sensors (Chen et al., 2019; Spagnolo et al., 2019). Furthermore, in its evolving usage context, particularly in barcode scanners, the current trend in barcode scanners integrates the principle of the photoelectric effect as a central element, in response to the increasing demand for accuracy and efficiency. The widespread use of barcode scanners has driven the development of systems relying on directed laser beams to reflect light from barcodes, while sensitive photoelectric sensors measure the reflected light variability, enabling precise data decoding (Fornalski, 2018; Sunyono & Sudjarwo, 2018). The combination of the photoelectric effect and barcode scanning technology continues to evolve and holds great potential in various optics-based technological applications.

Despite the well-established nature of the photoelectric effect and its various applications, students often encounter difficulties in understanding its concepts. One of these challenges involves abstract

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concepts related to understanding how photons of light can liberate electrons from the surface of metals (Cai et al., 2021; Qian, 2023). Furthermore, grasping the relationship between light intensity, frequency, and photon energy can also be complex. Students also face difficulties in mathematically explaining the photoelectric effect experiment, given the existence of formulas that incorporate Planck's constant and the work function of metals (Lopez-Segovia et al., 2023).

Ineffective teaching methods in explaining these concepts in a manner that is not well understood by students also contribute to the failure of learning in this subject matter (Subali et al., 2019). Furthermore, according to Arista et al. (2018), presenting too much information or concepts at once can lead to student confusion. The lack of student interaction in learning, such as asking questions, or a lack of understanding of the relevance of the material to everyday life, can be obstacles to student comprehension. These difficulties can reduce the level of understanding and scientific attitude of students in dealing with complex topics such as the photoelectric effect. Therefore, attention is needed on how this material is taught and how classroom interaction can be enhanced to help students overcome difficulties that arise during the learning process. In this regard, clear instructions and in-depth presentation methods can assist students in overcoming these challenges and gaining a better understanding of the concept of the photoelectric effect.

To address students' difficulties in understanding the concept of the photoelectric effect, several approaches can be applied. These include presenting the material gradually and clearly while avoiding information overload. Teachers can explain these abstract concepts using analogies that are easier to understand and relate them to real-world applications in everyday technology, such as solar panels and barcode scanners. The lack of practical learning activities, often due to limitations in laboratory equipment related to modern physics subjects, can also be overcome (Pattiserlihun & Setiadi, 2020). Additionally, teachers should encourage active student interaction through relevant questions and discussions to clarify understanding. With a more structured and in-depth approach, students will find it easier to overcome difficulties and develop a strong understanding of the photoelectric effect.

One highly effective solution to address students' difficulties in understanding the concept of the photoelectric effect is by integrating interactive learning media that support comprehension (Wibowo et al., 2019). Therefore, teaching methods that can utilize and integrate various media and approaches for students are needed. Teachers can leverage instructional videos, computer simulations, or specialized educational applications designed to explain these concepts in a more visual and interactive manner (Shurygin et al., 2022). By using these media, students can directly observe how light influences electrons at the atomic level, aiding in a more concrete understanding of the concept (Husnaini & Chen, 2019). Additionally, learning media can facilitate virtual experiments that allow students to actively engage in understanding the photoelectric effect. Through a combination of more interactive teaching approaches and the utilization of learning media, students will find it easier to overcome difficulties in understanding the photoelectric effect. One such learning media that can be utilized is virtual laboratories.

A discovery-based virtual laboratory is one instructional media that can be highly beneficial in helping students acquire a deep understanding of the concept of the photoelectric effect. With this virtual laboratory, students can conduct virtual experiments, allowing them to manipulate parameters such as light intensity, frequency, and different types of metals, and directly observe how these changes affect electron emission. The discovery learning approach gives students the freedom to explore and test concepts independently, which can enhance their understanding (Apriani et al., 2020; Gutiérrez et al., 2022). Additionally, virtual laboratories also provide opportunities to visualize abstract concepts, which are often difficult to grasp through text explanations alone (Mandagi et al., 2021; Susilawati et al., 2021). By using instructional media such as discovery-based virtual laboratories, teachers can offer a more interactive and enjoyable learning experience for students, ultimately aiding them in better understanding the photoelectric effect. Moreover, learning through experimentation helps students become proficient in the scientific process.

In addressing students' difficulties with the topic of the photoelectric effect, it is also crucial to foster a positive scientific attitude during the learning process (Astuti et al., 2020; Tiwi et al., 2019). Teachers can encourage students to develop attitudes of curiosity, precision, and courage in asking questions and seeking deeper understanding of the concept of the photoelectric effect. Students' scientific attitudes in studying the photoelectric effect are essential to ensure a deep understanding of this concept. In this learning context, students need to be developed in terms of observation, experimentation, and data analysis (Shurygin et al., 2022; Suastra & Ristiati, 2019). Students should have an open mindset towards experiment results that may not always align with their expectations, as this is part of the true scientific process (Priska et al., 2021; Ratnasari et al., 2018). Students need to learn to investigate, try various approaches, and delve deeper to overcome any difficulties that may arise (Kurniawan et al., 2019). Additionally, it is crucial for students to have perseverance and determination in understanding complex concepts such as the photoelectric effect. A strong scientific attitude, which includes a high level of curiosity, precision in observation, courage to ask questions, and the ability to seek deeper understanding of the concept of the photoelectric effect, will greatly assist students in overcoming challenges during their learning journey. This attitude will also motivate students to actively participate in experiments, data analysis, and class discussions (Kurniawan et al., 2019; Mediartika & Aznam, 2018). Therefore, students' scientific attitudes in studying the photoelectric effect play a crucial role in helping them overcome difficulties and achieve higher competencies in the field of science. Students are also taught not only to accept information but also to seek explanations through exploration and experimentation. Therefore, the use of instructional media such as discovery-based virtual laboratories not only helps students understand concepts but also fosters scientific attitudes that can have long-term benefits in the learning process and the development of critical thinking skills (Buxner et al., 2018; Isnaeni et al., 2021). With a combination of interactive learning approaches and the development of scientific attitudes, students will be better prepared to overcome difficulties in understanding the photoelectric effect and face other learning challenges.

Virtual laboratories can enhance conceptual understanding and practical skills, as shown in research conducted by Susilawati et al. (2021), indicating that the use of virtual laboratories with electronic workbenches can lead to better conceptual understanding of physics literacy and practical skills related to scientific procedures. This suggests that virtual laboratories not only improve theoretical understanding but also strengthen students' practical skills in the context of physics experiments. Meanwhile, research by Santoso et al. (2020) found that simulations in virtual laboratories allow students to conduct electrical circuit experiments similar to direct experiments in physical laboratories. Additionally, research by Sutarno et al. (2019) explains that virtual laboratories can visualize abstract and challenging concepts, thus enhancing students' thought processes.

Research on the implementation of discovery-based virtual laboratories in physics education, particularly in the context of the photoelectric effect, is important because it significantly contributes to enhancing students' conceptual understanding and practical skills, expanding accessibility and efficiency in physics learning, increasing student engagement and attractiveness, and opening opportunities to improve critical thinking and creativity in understanding and applying physics concepts. The urgency of this research is crucial because current learning tends to be more technology-oriented, especially those based on virtual platforms (Lestari et al., 2023; Sari et al., 2020). Its goal is to provide convenience to users, both in educational institutions and educational observers, that technology has become an essential and inseparable part of advancing education, especially in instructional media (Utami et al., 2022; Zulkifli et al., 2022). Additionally, this research serves as a complement to learning activities because not all schools have quantum physics laboratory facilities.

This article discusses the implementation of discovery-based virtual laboratories in physics education, specifically focusing on the photoelectric effect, to enhance students' scientific attitudes. The application of discovery-based virtual laboratories is an innovative step in physics education, enabling students to explore and experiment interactively with scientific concepts through simulations. By utilizing this media, students not only understand theory but also experience physics concepts firsthand. Therefore, the use of virtual laboratories in photoelectric effect education can create a dynamic learning environment, motivating students to be more engaged in learning, and ultimately enhancing students' scientific attitudes towards physics.

Method

The research framework is outlined as follows.

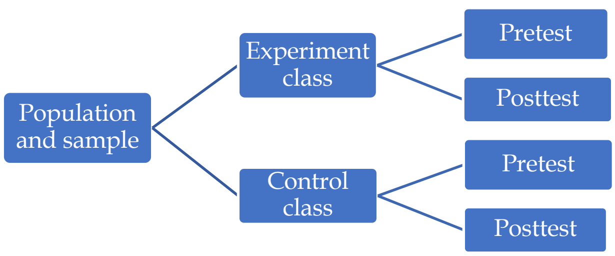

Figure 1. Research stage

This research utilizes the quasi-experimental research design within a quantitative method. The research design employed is pretest-posttest, with nonequivalent multiple-group design. To facilitate the research process, the sequence of this research framework is outlined as follows.

Population and Sample

This research was conducted at SMAN 2 Yogyakarta, with a population of 72 students consisting of two classes, namely Class XII MIPA 4 and Class XII MIPA 5, each class comprising 36 students. SMAN 2 Yogyakarta was chosen for this study because it represents a population of students who often face difficulties in understanding the concept of the photoelectric effect.

Research Design

This study adopted a quasi-experimental design with the division into two groups: the control group and the experimental group. Class XII MIPA 5 was considered the control group, which would receive conventional teaching methods with learning materials in the form of lecture notes. On the other hand, Class XII MIPA 4 was considered the experimental group, which would receive instruction using a virtual lab-based discovery learning approach.

Data Collection Procedure

Data in this study were collected through two main techniques: classroom observation and the use of questionnaires. Classroom observations were conducted in both classes to observe the interaction between the teacher and students and the implementation of the teaching process. Observations were carried out by three trained observers who observed student behavior and the dynamics of the learning process. Questionnaires were used to measure the development of students' scientific attitudes. The questionnaire instrument was designed based on aspects of scientific attitude such as curiosity, precision, and courage in engaging in the scientific process. Questionnaires were given to each of the 36 students in Class XII MIPA 5 (the control group) and 36 students in Class XII MIPA 4 (the experimental group) before and after the learning period as an assessment tool for the development of students' scientific attitudes.

Data Analysis

Data collected from the questionnaires will be analyzed using descriptive statistical methods to measure changes in students' scientific attitudes. Additionally, differences between the control group (Class XII MIPA 5) and the experimental group (Class XII MIPA 4) will be evaluated using appropriate statistical tests such as the t-test. Data analysis will be conducted using statistical software such as SPSS.

Result and Discussion

Development of Students' Scientific Attitudes Before and After Learning

To evaluate the development of students' scientific attitudes, a questionnaire instrument was used, which covered aspects of scientific attitudes such as curiosity, precision, and courage in engaging in the scientific process. This questionnaire was given to 36 students in Class XII MIPA 5 (the control group) and 36 students in Class XII MIPA 4 (the experimental group) before and after the learning process.

The results of data analysis showed significant changes in students' scientific attitudes after the learning process. In the control group (Class XII MIPA 5), there was a less significant increase in students' scientific attitudes, while in the experimental group (Class XII MIPA 4), a higher increase was observed. This result was supported by statistical comparisons using the t-test between the two groups, which indicated a significant difference in the development of students' scientific attitudes ($p<0.05$). The results of students' scientific attitude questionnaires are shown in the following Figure 2.

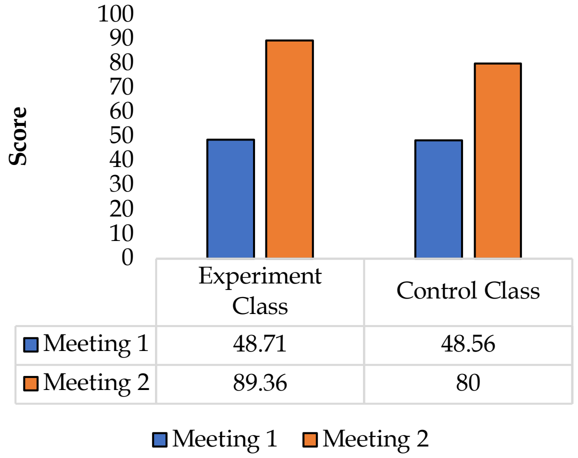

Figure 2. Improvement in scientific attitudes

Based on Figure 2, which illustrates the increase in scientific attitude in the experimental class with an average of 89.36 in the second meeting, while the control class had an average of 80.00 in the second meeting. This indicates a change in scientific attitude from the first meeting, with the most significant change observed in the experimental class. To further examine this change significantly, an independent t-test was employed. The analysis of the improvement in students' scientific attitudes through the independent t-test can be observed in the following Table 1.

Based on Table 1, the obtained significance result of 0.00 indicates a significant difference in the variances between the experimental and control groups regarding scientific attitudes. In other words, the treatment provided to students significantly improved their scientific attitudes. This demonstrates the effectiveness of the intervention in changing students' attitudes towards science or scientific methods using the virtual lab.

Table 1. Results of Independent t-Test

Independent samples t-test										
Levene's test for equality of variances				T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
Student scientific attitude	Equal variances assumed	.00	.99	5.04	70	.00	5.78	2.93	8.93	20.63
	Equal variances not assumed			5.04	70	.00	5.78	2.93	8.93	20.63

Furthermore, classroom observations were conducted to observe the interaction between teachers and students, as well as the implementation of learning media in the learning process. The observation results show that the use of learning media in the form of a virtual lab based on discovery learning in class XII MIPA 4 has increased student interaction with learning materials and stimulated students' interest in understanding the concept of the photoelectric effect. The use of virtual labs based on discovery learning in this experimental class observed an increase in interaction between teachers and students, with more questions and discussions from students related to learning materials, indicating active engagement in the learning process.

Students' curiosity to understand concepts is supported by their ability to analyze evidence and data that support a concept or argument. Additionally, students demonstrate critical thinking by organizing and interpreting information critically, not merely accepting information at face value. There is also an openness to changing concepts or views based on new evidence or information found. Students' involvement in group work and their ability to communicate effectively in class discussions reflect a scientific attitude in terms of cooperation and communication. Patience and perseverance are evident in students' efforts to overcome difficulties or challenges that arise during the learning process. Moreover, it is observed that students show respect for various perspectives and opinions, reflecting their awareness of diversity in viewpoints. Other indicators involve students' desire to delve deeper into concepts, seek relationships, and identify patterns, demonstrating a high curiosity towards the learning material. Finally, students' interest in the scientific process and their desire to understand it more deeply add another dimension to the observed scientific attitude. Thus, the qualitative observation results reflect that students in the class exhibit positive and active scientific attitudes in approaching learning.

Discussion

The instructional media used was a virtual lab based on discovery learning in HTML 5 format. Therefore, this instructional media can only be accessed online using a laptop or smartphone and can be used anytime and anywhere. The appearance of the virtual lab is as shown in the following Figure 3.

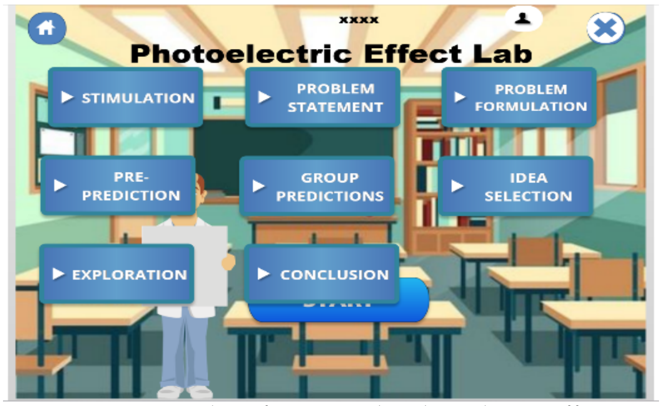

Figure 3. Display of menu in the photoelectric effect experiment

Figure 4. Display of experimental equipment

In the virtual lab practical activity, the aim is for students to understand the relationship between incoming light (with varying wavelengths and intensities) and the resulting photocurrent. The learning objectives for this topic emphasize visualizing abstract concepts so that students can comprehend the workings of the photoelectric effect concept. This is achieved through the use of specially designed simple equipment. Therefore, the use of media in the form of a virtual lab can assist in enhancing student engagement with abstract and challenging concepts through scientific investigation (Husnaini & Chen, 2019; Purwaningtyas et al., 2022).

This experiment also aims to calculate the Planck constant, explain the linear relationship between photon energy and frequency, and demonstrate that the stopping voltage does not depend on the intensity of the incoming light. Hence, this presented experiment not only enhances a deeper understanding of the corpuscular nature of light among students but also encourages students to adopt a scientific attitude that includes curiosity, careful observation, the ability to design valid experiments, and the courage to test hypotheses. This scientific attitude is crucial in the learning process as it helps students develop skills and a deeper understanding of science.

The use of virtual labs in physics education for assessing students' attitudes is easily observable. Virtual labs enable detailed data collection on students' activities, allowing teachers to monitor students' progress in real-time and provide more timely feedback (Purwaningtyas et al., 2022). Furthermore, a virtual lab grounded in discovery learning, supported only by limited guidance and instructions, can assist students in exploring concepts independently while still receiving necessary guidance (Gutiérrez et al., 2022). Therefore, virtual labs also have a positive impact on students' abilities to explore and foster attitudes in the scientific process.

Research by Pattiserlihun et al. (2020) states that virtual laboratories are effective tools for use in the learning process and discussions to strengthen concepts and knowledge related to modern physics, which are often microscopic and not visible to the naked eye. Furthermore, research by Cai et al. (2021) on the effectiveness of physics learning using virtual laboratories shows that the use of virtual experimental media is also effective in improving physics learning, especially in the topic of the photoelectric effect, particularly in abstract concepts. Experiments with virtual labs allow students to observe the photoelectric effect, which is often difficult to observe in a classroom setting. Virtual lab media enables students to actively engage in the scientific learning process, especially in gaining a deeper understanding of physics concepts.

Another study by Gunawan et al. (2019) states that virtual labs can enhance students' scientific attitudes. This may be because virtual lab-based discovery learning eases students' understanding of physics materials, specifically the photoelectric effect, which stimulates students' curiosity. This is because the virtual lab was developed using a discovery learning approach, which can stimulate students' curiosity because virtual labs using this approach encourage students to explore concepts and knowledge independently (Jannah et al., 2021). In the virtual lab used, there is a practical section that includes discovery learning syntax and encourages students' scientific attitudes through stimulation activities, problem statements, problem formulation, pre-prediction, group predictions, exploration, and conclusions. Each part of the practical work requires students to analyze, thus enhancing their scientific attitudes during the learning process. This activity in physics education plays a role in providing opportunities and learning experiences for students, enabling them to actively participate in experimental activities (Sulaiman et al., 2023; Zulkifli et al., 2022). The use of virtual learning media has several advantages, such as being accessible anytime and visualizing difficult and abstract concepts, which may not be possible in physical activities (Husnaini & Chen, 2019; Sari et al., 2020).

Students can actively participate in the learning process, especially in exploration activities in each practical step in virtual lab learning (Syukri et al., 2022). The use of virtual labs allows students to conduct virtual physics experiments without the need for complex physical equipment. Furthermore, virtual labs enable students to visualize and observe abstract physics concepts more clearly. Practical activities that sharpen analysis skills will enhance students' scientific attitudes. This also makes students actively involved in experiments and observations, supporting a scientific learning approach. Overall, scientific attitudes improve after learning with virtual lab-based discovery learning. Therefore, the use of virtual laboratories can address some of the challenges faced by inadequate laboratory equipment and positively contribute to achieving learning goals.

A virtual laboratory can be utilized flexibly in classroom learning. This approach provides students with opportunities to employ technology in understanding physics concepts. Such activities will enable students to explore and develop understanding through virtual experimentation (Apriani et al., 2020; Pramuda et al., 2019). This can be effectively combined with various methods, media, and other pedagogical aspects. The virtual laboratory discussed in this context is included in online learning, where the learning process can be blended with face-to-face interactions. Engaging in learning activities with virtual laboratories can aid in improving students' learning abilities and affective attitudes (Klein et al., 2021). Scientific attitudes, which are the focus of this discussion, are more apparent when learning also includes face-to-face interactions. The behavioral attitudes of learners can be observed through sharing learning theories, one of which is behaviorism. Learning with virtual laboratories can be conducted using a behaviorist approach, where scientific attitudes of learners can be observed and enhanced due to the habituation involved in this learning process.

The use of virtual labs significantly enhances students' scientific attitudes. The flexibility of access allows students to independently explore topics, stimulating a sense of research enthusiasm and curiosity. Visualizing difficult and abstract concepts through visual elements such as animations and simulations not only facilitates better understanding but also develops observation and interpretation skills. Through online collaboration and participation in scientific discussions, students not only sharpen social skills but also cultivate a critical approach to information by considering various perspectives. Instant feedback from tasks and exercises encourages a stance of continuous reflection and improvement, while hands-on experience through virtual simulations and experiments brings students closer to scientific methods. Overall, virtual learning media serve not only as a means of information delivery but also as a platform for shaping scientific attitudes involving exploration, criticism, and collaboration.

Conclusion

Implementation of virtual laboratories based on discovery learning in teaching about the photoelectric effect has been proven to be highly effective in enhancing students' scientific attitudes. This innovative approach not only aids in understanding abstract concepts related to the photoelectric effect but also fosters a deep understanding of its underlying principles. Research results indicate a significant improvement in students' scientific attitudes, particularly in the experimental group exposed to virtual laboratory learning. Virtual laboratories provide an interactive and engaging environment for students to explore and experiment with scientific concepts. Moreover, it encourages students to adopt scientific attitudes such as curiosity, accuracy, and the courage to ask questions and seek deeper understanding. These scientific attitudes are crucial for achieving a profound understanding of complex concepts such as the photoelectric effect. Thus, the utilization of virtual laboratories based on discovery learning has great potential in enhancing both learning experiences and scientific attitudes in physics education.

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Conflicts of Interest
There are no conflicts of interest to declare in this research.

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