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Utilization of PhET Simulations in Replacing Real Laboratories for Physics Learning

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Abstract

The purpose of this research is to find out the benefits of PhET simulation in teaching physics in schools, and to argue that PhET simulation can replace real laboratories in teaching physics in schools. This research is a qualitative research. This type of research is literature study. Articles to be reviewed are obtained from various sources, namely: Google Scholar, Scopus, Garuda portal and ERIC. The first stage of the search produced 50 articles, then the data was directed to the selection of 10 main challenging categories to be researched, 3 international journals and 7 national journals. The results of the study show that teachers can use PhET simulations as an alternative complementary solution to the unavailability of real physics laboratory equipment in schools. PhET simulations are not only a substitute for real laboratories. In its implementation, PhET simulation is able to display real practical processes clearly and easily understood. PhET Simulation improves academic achievement in the field of science, improves student performance, thinking skills and enhance students' interaction. Changing abstract concepts into more concrete ones. The PhET simulation also has disadvantages, namely that teachers and students must provide electronic devices that have the PhET application installed; must master the use of electronic devices; require usage guidelines; does not include activities; not yet equipped with student worksheets; no instructions for use yet; and students must work independently.

Keywords: *PhET, Laboratory, Physics*

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1. Introduction

Technological growth occurring in the global world are the fundamental rationale for the needs to integrate computer-based teaching methods in education, becoming a rapidly growing trend [1], [2]. Education, especially in the fields of science, technology, engineering and mathematics, requires attention to the importance of simulation and applied learning [3]. Computer simulations are interactive programs that provide models or systems of natural or artificial phenomena.

Interactive computer simulations and attractive interfaces accompanied with display and manipulation features can be used simultaneously. This simulation tool can accompany students to play back videos or simulations of their experiments, so that students develop a concrete understanding of scientific phenomena demonstrated through simulations [1]. This simulation mediates teachers in teaching complex and abstract physics concepts and assists students to develop skills in experiments [2], [5]. Technological advances have produced a lot of software and tools that can be adopted to facilitate the achievement of physics learning goals. One of technology tools that is widely used in physics learning is PhET simulation. It has many features [2]. PhET simulation is considered one of the world's best educational software, because it can be accessed for free and saved as a web page, jar file, or SWF file that can be operated using a flash drive [6]. PhET simulations are also research-based, interactive, use animation and easy to use. PhET simulation shows an environment that resembles the original, which can be used to model real world situations, and does not require a more specialized computer [2]. PhET simulations provide students with the opportunity to learn physics in a different way through the visualization of interesting physics concepts, so that students can understand abstract physics concepts [7], [8].

PhET simulation is a research-based science and mathematics simulation that is fun and interactive, capable of representing information in various representations (visual, verbal, and mathematical) [9], [10]. PhET simulation consists of 130 simulations of various aspects of science and mathematics [11]. Each PhET simulation has learning objectives, a brief description of the topic, tips for teachers, class activities, teacher resources and mini laboratory activities, difficulties faced by students, and class suggestions [7]. PhET simulation-based learning provides visualization and teaching aids that help easily understand content knowledge, thereby improving students' achievement and learning motivation [12], [15], skills in conducting experiments [16], [17], problem solving skills [18], independent learning [19], and providing high interactive contributions and dynamic feedback [6].

Facilities in schools generally include learning resources, facilities and infrastructure as well as the use of technology for learning. Currently, many schools use learning media in the form of KIT media, but its use is still limited. Since not all schools have this KIT media. The use of technology as a learning medium, such as the use of PhET simulations, can be used by teachers as an alternative complementary solution to the limitation of real physics laboratory equipment in schools, so PhET simulations are not only a substitute for real laboratories. In its implementation, the PHET simulation is able to display real practical processes clearly and easily understood, thus improving students' abilities both cognitively, affectively and psychometrically. Based on this explanation, this study scrutinized case on the Utilization of PhET Simulations in Replacing Real Laboratories for Physics Learning. The purposes of this study are 1) to find out the benefits of PhET simulation in learning physics at school; and (2) to suggest that PhET simulations can replace real laboratories in teaching physics at school.

2. Methods

This research is a qualitative research. Qualitative research is a research method based on the philosophy of post-positivism, used to examine natural object conditions where the researcher is the key instrument. Data sampling is carried out purposively and snowball [9]. Data collection techniques are triangulation (combined), data analysis is inductive/qualitative in nature, and the results of qualitative research emphasize the meaning of generalizations. This type of research is a literature study in which the researcher reviews previous research which is considered to have benefits for the relevant information she has obtained.

The research samples in this study were articles taken from national and international journals selected from publications of various years which referred to issues and research trends to be discussed which are multi-year issues.

Articles to be reviewed are obtained from various sources, namely: Google Scholar, Scopus, Garuda portal and ERIC. The first stage of the search produced 50 articles, then the data was directed to the selection of 10 main challenging categories to research, 3 international journals and 7 national journals. The literature review can be analyzed in six components, namely: (a) the database used to select articles; (b) the theoretical framework used to conduct the literature review; (c) tools; (d) integrative tables and their contents; (e) the method used to categorize articles and synthesize the findings in the articles. A schematic picture of a systematic literature review can be seen in Figure 1.

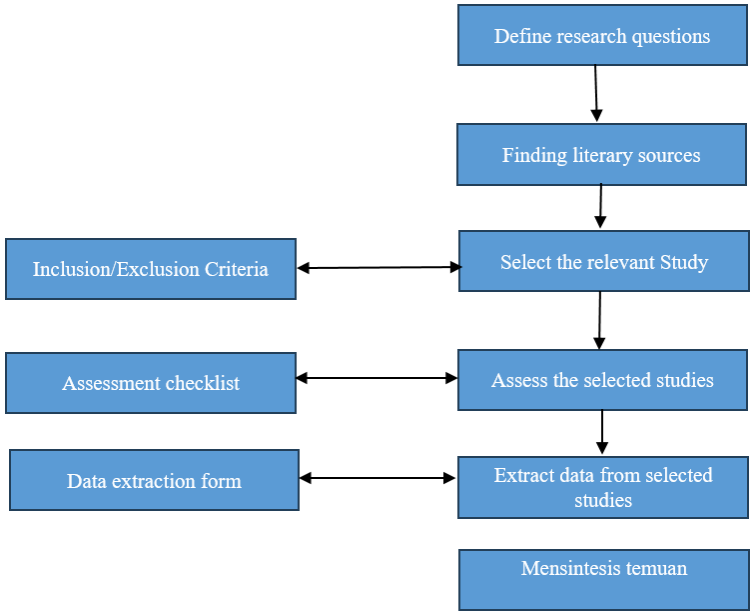

Figure 1. Systematic Scheme of Literature Review

3. Result and Discussions

3.1. PhET Simulation in Physics Learning

Physics learning must be taught in a constructivist way. Effective physics learning requires well-designed and varied instructional tools, such as the use of science and technology in the learning process. The use of science and technology in the learning process has been predicted for a long time. Science and technology change text sources in textbooks into computer-based images, animations or videos [10]. Learning by using science and technology can stimulate students to (a) use scientific processes in problem solving and decision making; (b) understand the fundamental elements of science and technology; (c) critically analyze the latest scientific knowledge and its role in society [11]; (d) improve conceptual knowledge [12].

The process of delivering material in physics learning is not enough just with classical activities, but it is necessary to practice and introduce the real phenomena. Thus, the learning is very closely related to laboratories and practicum [13]. The laboratory in learning physics has a very important role, because the laboratory can train students to improve their skills in observing, classifying, measuring, communicating, interpreting data and arranging conclusions. Learning physics will be more interesting and fun if accompanied by practical activities in the laboratory. In addition, learning in the laboratory can improve metacognitive skills [14].

One of the uses of science and technology as a substitute for laboratories in physics learning is by using PhET simulations. PhET Simulation is a website developed by the University of Colorado that provides various simulations for both classroom and individual learning. PhET simulations are used by teachers to assist in explaining lessons to students, teachers can explain directly abstract subject matter as proven through simulations [15]. Visualizations in PhET simulations can help students see inaccessible processes and structures effectively. PhET simulations can be used by students to see details or do experiments many times [16].

3.2. Barriers and Advantages of Using PhET Simulation in Physics Learning

Along with the development of technology, learning physics can utilize technology as a substitute for practicum in the laboratory. Along with the use of PhET simulations in replacing practicum in learning physics, there are several advantages and obstacles to using technology in learning physics. The advantages and disadvantages of using PhET simulations in learning physics can be seen in Table 1.

Table 1. Advantages, Barriers and Solutions to Utilizing PhET Simulation in Physics Learning

No	Strengths	Challenges	Solutions
1	Reducing time constraints, geography, and provident [17][18]	Teachers and students must provide electronic devices: smartphones and computers that have the PhET application installed [7]	Schools improve the quality of facilities such as providing computers and internet networks [19]
2	PhET simulation has good experimental quality [17]	Teachers and students must master the use of electronic devices. Requires guidelines for using PhET learning media [17]	Need to improve the ability of teachers and students in the use of electronic devices [20], teachers attend training regarding the use of applications to support the learning process [19].
3	PhET simulation helps students in the learning process in the laboratory [21]	The PhET simulation program does not include activities to facilitate student understanding [22]	The use of PhET simulations is accompanied by inquiry-based learning [23], using Youtube videos [12], using a scaffolding approach [24], STEM-based PhET [25], using Zoom [26], using Google products [27]
4	Minimizing mistakes in doing practicum [28]	Student worksheets not yet completed [29] There are no instructions for use yet [30]	Develop student worksheets [31]
5	All experimental tools needed in practicum activities are available in the PhET program [4]	Students must work independently	The use of PhET simulations is accompanied by the use of student-oriented learning strategies [7]

The use of this PhET simulation is being developed in learning activities. In particular, learning physics requires the selection of types and strategies that are in accordance with the teacher's competencies, character, and goals. PhET simulations can carry out various experimental activities that cannot be carried out in real terms. PhET simulation media can be accessed for free through the website https://PhET.colorado.edu by teachers and students. PhET can be applied with a computer, or through a smartphone browser, to be combined in another application such as PowerPoint, Android applications or Nearpod and others. This PhET simulation is HTML-based [7].

3.3. The Effectiveness of Learning Physics with PhET Simulations

A learning can be said to be successful if every learning activity carried out gets optimal results. Education in the 21st century and the 4.0 revolution does not only require students to be able to use technology, but also master the material. Utilization of this PhET simulation can be used as a mediator to improve student learning outcomes. Utilizing PhET as a substitute for a real laboratory will improve student involvement to actively participate in the learning process.

Many challenges in the implementation of learning physics. Some of these challenges include: innovative science teaching, classroom and school connectivity, and classroom management changes. To overcome these problems, teachers can use virtual labs to replace real laboratories, namely PhET simulations. Based on the analysis that has been carried out, namely the process of exchanging information in cyberspace can be applied to the teaching and learning process where various shortcomings of ordinary face-to-face meetings can be carried out using PhET simulations. Utilization of PhET simulations to improve the quality of the learning process and implement science and technology [32]. PhET simulation improves academic achievement in science [33][34], improves student performance [35], thinking skills [36], engages student interaction [37][38][39]. PhET simulations turn abstract concepts into more concrete ones, so that they can help students understand concepts even better [40].

The phET simulation is used for several reasons, for there are no tools to carry out practicums in schools, apart from that because by using a virtual laboratory we can observe abstract aspects that cannot be observed through direct practice as well as current conditions that recommend being able to do online learning [18]. Other benefits of PhET simulation are: (a) students can practice individually or in groups anytime and anywhere; (b) students can repeat practical activities so as to increase learning effectiveness; (c) minimize time; (d) economical; (e) security and safety are better maintained [39], [40] The use of PhET simulations as a substitute for real laboratories in physics learning can meet the demands of 21st century education and the 4.0 revolution. Teachers need to emphasize that it is important for students to learn not only about science and technology mastery but how to use it. Learning practices developed by utilizing technology.

4. Conclusion

Physics learning contains a lot of abstract concepts so that it makes students feel difficult in learning physics. Many challenges in the implementation of learning physics. Some of these challenges include: innovative science teaching, classroom and school connectivity, and classroom management changes. To overcome these problems, teachers can use virtual labs to replace real laboratories, it is PhET simulations. PhET simulation can meet the meeting's shortcomings in the direct classroom learning process. PhET simulation turns abstract concepts into more concrete ones. So that, teachers can help students understand concepts more better.

Utilization of PhET simulations is to improve the quality of the learning process and implement science and technology. PhET simulation improves academic achievement in science, improves student performance, thinking skills and improves student interaction. PhET simulation also has some weaknesses, these are teachers and students must provide electronic devices: smartphones and computers that have the PhET application installed; teachers and students must master the use of electronic devices; requires guidelines for using PhET learning media; the PhET simulation program does not include activities to facilitate student understanding; not yet completed with student worksheets; no instructions on how to use; and students must work independently. It is hoped that future researchers will utilize PhET simulations to replace real laboratories in the physics learning process and integrate PhET simulations with other learning models. Before conducting research, researchers must consider about school context where the research will be conducted in order to be optimally implemented.

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