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PhET INTERACTIVE SIMULATIONS FOR SCIENCE LEARNING IN ELEMENTARY SCHOOL

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Abstract: This research investigates the effectiveness of implementing PhET Interactive Simulations as a virtual laboratory in elementary school science education. The research method employed is qualitative descriptive with data collection techniques including literature review, questionnaires, observations, and interviews. Data analysis was conducted using Miles and Huberman's data analysis technique. The results of the analysis indicate that PhET Interactive Simulations are effective in enhancing students' understanding of scientific concepts. Students can actively engage in virtual laboratory activities using PhET Interactive Simulations, which helps make learning more meaningful. This application also succeeds in visualizing concepts that were initially difficult to comprehend. Therefore, this research concludes that PhET Interactive Simulations are effective as a virtual laboratory in elementary school science education.

Keywords: PhET Simulation; Science Learning; Elementary School

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INTRODUCTION

Science education at the elementary school level has a very important role in forming students' basic understanding and interest in natural science. At this stage, students begin to build their knowledge and understanding of fundamental science concepts, which will become the foundation for further learning at a higher level. Natural science not only teaches concepts but also teaches how these concepts are obtained through a series of observations and experimental activities using scientific methods. Based on research results, Ghasya & Johan (2021) explained that online learning was felt to be less effective because the material was not conveyed in its entirety to students, the activities most often carried out were just providing materials and assignments and collecting assignments. Difficulty in understanding the subject matter is also one of the obstacles faced by students in online learning (Putri, Kuntarto, & Alirmansyah, 2021). This results in learning not being able to run optimally and psychomotor skills not being trained properly.

Advances in information and communication technology (ICT) have provided new opportunities in developing more interactive and effective science education. One innovation that stands out in this context is the use of computer-based educational applications. This technology is not only a learning aid but also provides an opportunity to create a more interesting and powerful learning experience.

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One of the innovations that stands out is the use of computer-based educational applications. This app allows students to actively explore, participate in virtual experiments, and visualize science concepts more dynamically. With easy access to technology and computer devices, elementary schools have the opportunity to utilize these educational applications as effective teaching tools.

In recent years, computer-based educational applications have become an increasingly popular means of teaching science at the elementary school level. This application has the potential to increase understanding of science concepts through a more interesting, visual, and interactive practical experience for students. With easy access to technology and computer devices, elementary schools have the opportunity to utilize these educational applications as effective teaching tools.

One computer-based educational application that stands out in this context is PhET Interactive Simulations. PhET (Physics Education Technology) is a simulation media developed by Katherine Perkins from the University of Colorado, United States (Rizaldi, Jufri, & Jamaluddin, 2020). PhET is an educational project that aims to provide free access to a variety of interactive simulations on various science topics. This application has achieved widespread use by teachers and students around the world. Its popularity is not only due to its free access but also due to its extraordinary ability to facilitate the understanding of complex science concepts through a highly effective visual and interactive approach. With PhET Interactive Simulations, students can learn more deeply and actively while exploring science concepts practically through interesting and informative simulations.

PhET interactive simulations are created in Java or Flash format, so they can be directly accessed from the website using a standard web browser. Through the site http://phet.colorado.edu/, PhET users can download and install the entire website (approximately 60 MB) for offline use (Perkins, Adams, Dubson, Finkelstein, Reid, Wieman, & LeMaster, 2006). PhET interactive simulations users can download the application via the Android Google Play Store to make simulations easier and more practical (Akinwale & Kehinde, 2017). PhET is an interactive simulation of physical phenomena, based on research, which is provided free of charge (Hikmawati, Sutrio, & Kusdiastuti, 2019). PhET contains learning simulations for physics, biology, chemistry, earth sciences, and mathematics. These simulations are based on research and are available for free to enhance the student learning experience. With PhET, science learning becomes more interesting, interactive, and easy to understand, helping students understand science concepts better.

Some of the advantages of PhET include 161 interactive simulations available, available in 97 languages (Indonesian, English, French, Arabic, Spanish, Turkish, Dutch, Italian, etc.), and there are 3043 lessons sent by teachers from various countries. The material contained in PhET interactive simulations has been categorized from elementary school, middle school, high school, to college. So, you can easily use it according to your education level. PhET interactive simulations have the aim of increasing student engagement improving learning and supporting students in building conceptual understanding through exploration activities.

However, despite its potential in increasing scientific understanding, the application of PhET Interactive Simulations in the context of primary school education in Indonesia is still relatively limited and has not been studied in depth. Therefore, this

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research aims to explore the effectiveness of implementing PhET Interactive Simulations as a virtual laboratory in science learning at the elementary school level.

By understanding the effectiveness of PhET Interactive Simulations in the context of elementary school education, it is hoped that this research will provide valuable guidance for teachers, educators, and curriculum developers in utilizing educational technology to improve students' science understanding and enrich their learning experiences. Apart from that, this research can also contribute to the scientific literature on the use of computer-based educational applications in science learning at the elementary school level.

METHOD

The method used in this research is a qualitative descriptive method. The research subjects in this study were 17 fourth-grade elementary school students. The selection of research subjects was carried out by researchers using purposive sampling techniques. The instruments used in this research were questionnaire sheets and interview sheets. The data collection techniques used in this research were literature review, questionnaires, observation, and interviews. The type of interview used in this research is a semi-structured interview. The type of questionnaire used in this research is a closed questionnaire, with alternative answers yes and no. Literature review carried out by researchers sourced from books, journal articles, and proceeding articles.

This research was carried out in three stages, namely the pre-field stage, fieldwork stage, and data analysis stage. In the pre-research stage, researchers prepared a research design in the form of guidelines for using PhET interactive simulations. At the fieldwork stage, researchers began conducting research by implementing PhET interactive simulations as a virtual laboratory in elementary school science learning, and distributing questionnaires, and conducting interviews at the end of the research. The research data was then analyzed.

The data analysis technique used in the research is the Miles and Huberman analysis technique. Miles and Huberman in Sugiyono (2013) stated that activities in qualitative data analysis are carried out interactively and continue continuously until completion so that the data is saturated. The stages in data analysis include data reduction, data display, and conclusion drawing/verification.

RESULT AND DISCUSSION

Questionnaire data was obtained using a questionnaire sheet instrument in the application of PhET as a virtual laboratory in elementary school science learning. This instrument was filled in by class IV students with the help of the teacher. This data aims to find out how students respond to the application of PhET as a virtual laboratory in elementary school science learning. The data is presented in Table 1 below.

Table 1. Recapitulation of Student Response Questionnaire on the Application of PhET

as a Virtual Laboratory in Science Learning

Question Number	Answer Score		Total Score	Percentage (%)
	Yes	No		
1	17	0	17	100
2	17	0	17	100
3	2	15	15	88.23
4	17	0	17	100
5	3	14	14	82.35
6	3	14	14	82.35
7	3	14	14	82.35
8	15	2	15	88.23
9	14	3	14	82.35
10	17	0	17	100

Based on table 1, it can be seen that the average percentage of students' positive responses to the application of PhET in science learning is very high, namely 90.59%. A total of 3 students or 17.65% still experienced difficulties in using PhET, both in terms of usage procedures and language, as well as in understanding the content of science material that can be studied with PhET. Taufik (2008) explains that PhET simulations can give a positive, interesting, entertaining impression and help explain in depth a natural phenomenon. Science itself is the process of finding answers to various natural phenomena that occur. PhET interactive simulations are fun and interactive research activities based on science and mathematics that can be used to represent information in various forms (visual, verbal, and mathematical) Ajredini, Izairi, & Zajkov (2013), Astutik & Prahani (2018), Finkelstein, Adams, Keller, Perkins, & Wieman (2006), and Perkins, Adams, Dubson, Finkelstein, Reid, & Wieman (2006) added that the features of PhET, visualization, interactivity, context, and effective use of calculations, are very effective for help students understand abstract concepts.

The application of PhET interactive simulations as a virtual laboratory in elementary school science learning uses an inquiry learning model, where students themselves will find answers to the problems they study in the form of scientific concepts. Various problem solvers are given to students in an effort so that they can find their solutions using PhET interactive simulation media. The use of PhET interactive simulation is combined with the steps of inquiry learning.

Apart from using questionnaire data, the data source in this research comes from interviews. The interview aims to gather information regarding any suggestions or input from students regarding the application of PhET interactive simulation media in elementary school science learning and to find out students' opinions on whether the media is suitable when used in science learning.

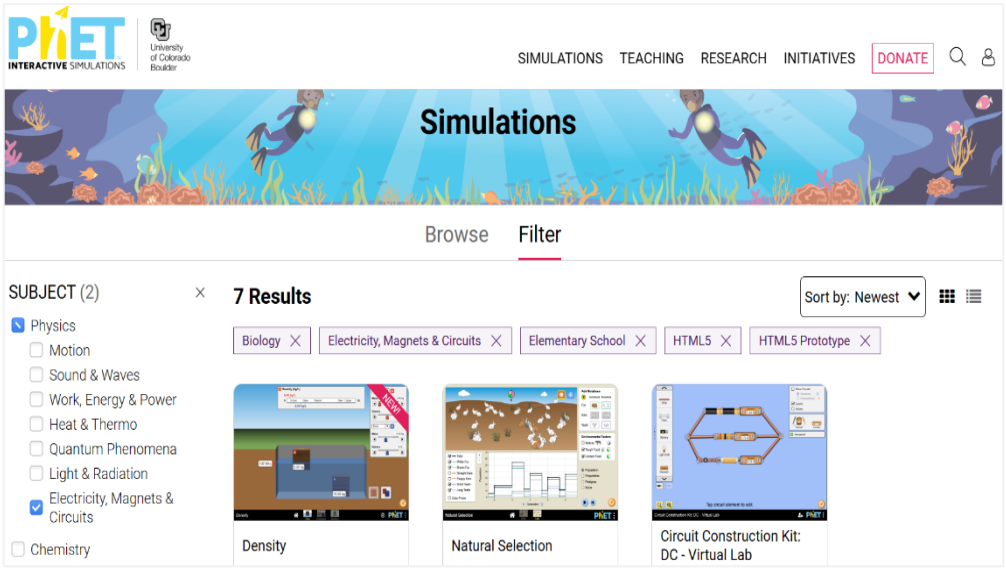
Based on the results of interview data, it show that PhET interactive simulations are very suitable for use in science learning to carry out virtual practicums. This is because with PhET media they can further improve their understanding of scientific concepts through practical activities. PhET interactive simulations can function as a virtual laboratory that can be done at home or in the classroom if limited by the availability of practical equipment and materials. Based on the research results of Hikmawati, Sutrio, & Kusdiastuti (2019) state that students at the elementary school level are not yet familiar

with PhET interactive simulations as a virtual laboratory, so it is felt necessary to apply PhET interactive simulations media.

PhET interactive simulations can also help educators to convey the science material that will be taught. Not all science material can be put into practice, while the aim of science learning is not only cognitive but also teaches various science process skills. The use of PhET interactive simulations is felt to be very helpful. They can discover science concepts, practice with problems, and so on. The research results of Haryadi & Pujiastuti (2020) state that the application of PhET interactive simulations can improve students' science process skills. Students are more interested in learning because the exploration of students' initial concepts is carried out through simulations and other visual displays in PhET related to energy material so that students can feel that the concepts taught are truly contextual and have direct contact with activities in their daily lives.

In essence, student learning outcomes consist of three domains, namely cognitive, psychomotor and affective domains. The biggest challenges in the psychomotor domain of students can be developed with the help of PhET interactive simulation media. This is supported by the research results of Prihatiningtyas, Prastowo, & Jarmiko (2013) which show that the implementation of PhET interactive simulations can improve student psychomotor learning outcomes.

Based on data from questionnaires and interviews, it can be seen that in general PhET interactive simulations are effective and efficient when used as a virtual laboratory in science learning. Students can discover scientific concepts for themselves with the help of PhET interactive simulations media so that learning will become more meaningful. These results are in line with the research results of Nurhayati, Fadilah, & Mutmainah (2014) which revealed that student learning outcomes in dynamic electrical material taught using demonstration methods assisted by PhET interactive simulations were more effective than student learning outcomes using conventional methods. The following can be seen in Figure 1 in the form of a PhET interactive simulation.



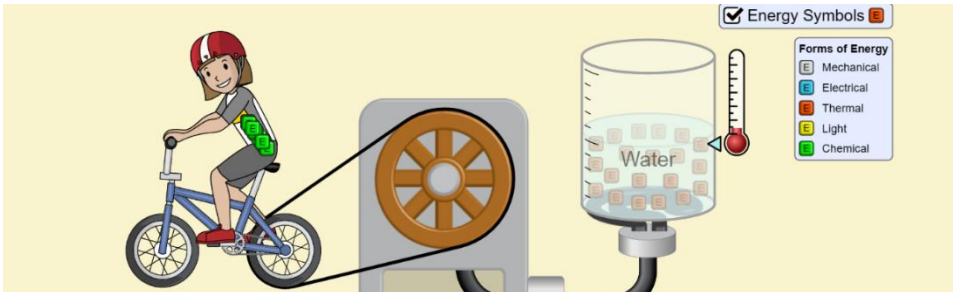


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Figure 1. PhET Interactive Simulation

In Figure 1, you can see the appearance of PhET interactive simulations, and the features contained in them as examples of science experiments. PhET interactive simulations provide materials that are suitable for elementary schools, such materials include balloons and static electricity, forms and changes in energy, electrical circuits, force and motion, etc. When using PhET interactive simulations we can also filter the material we want to use, the available filters are based on the fields of physics, chemistry, mathematics, earth sciences, and biology, as well as at what level of education. Simulation guides are available in various languages.

Based on questionnaire data and interview data, it can be seen that the PhET interactive simulation media is effectively applied as a virtual laboratory in elementary school science learning. This media has been proven to be able to properly visualize scientific concepts which were initially found to be difficult to understand because they are abstract, so that it will further improve students' understanding of the concepts/material being taught. Cavadas's (2021) research results show that implementing experiments using PhET interactive simulations affects students' critical thinking skills and learning outcomes. Science learning that trains critical thinking, will provide benefits to students, including: (1) helping students make decisions and solve problems, (2) applying knowledge, experience, and critical thinking skills, (3) channeling creative and innovative ideas, (4) overcome haste and narrow thinking, and (5) be open in receiving and giving opinions, make judgments based on reasons, and dare to argue critically and logically (Hasyim, Prastowo, & Jatmiko, 2020).

Research by Sarwoto, Jatmiko, & Sudibyo (2020) shows that there is a significant increase in online science learning outcomes with PhET simulation media. Apart from that, the application of PhET interactive simulations can be a solution to increase student creativity in science learning (Astutik & Prahani, 2018). Students can freely carry out experiments either with the help of worksheets provided by educators or they can try to carry out their own experiments, carry out calculations, and look for answers to their curiosity.

The advantages of applying PhET interactive simulations in learning according to Finkelstein, Adams, Keller, Perkins, & Wieman (2006), include: (1) presenting information about processes or concepts that are quite complex, (2) is independent in the sense that users can easily has been equipped with a guide, (3) it can increase students' learning motivation in class because of its attractive appearance, and (4) students can use

it both at school and at home. Another benefit that can be provided when learning using PhET interactive simulations is that PhET interactive simulations provide many macroscopic, microscopic, graphical, etc representations of many abstract concepts (Ceberio, Almudi, & Franco, 2016). Simulation is a method of replacing the system under study with a model that characterizes the actual system being tested with sufficient accuracy to obtain information about this system. Experimenting with models is called imitation (by imitating real reality, explaining the essence of phenomena without any experiments with real objects (Tuyboevna, 2021). Many technological applications can be used in natural science learning, for simulations, for example using crocodile physics and interactive physics (Onal, 2021), but there are still several obstacles, namely the scope of material presented does not accommodate natural science material, especially in elementary schools, obstacles language, and there is a fee that must be paid before using the application. Implementing online learning will enable students to be able to integrate natural science teaching materials which are equipped with digital literacy and can provide a more meaningful impression on students (Asrizal, Amran, Ananda, Festiyed, & Sumarmin, 2018). Apart from making science learning more meaningful, the application of PhET interactive simulation media can also reduce students' misconception levels better when compared to using teaching aids (Suhandi in (Rizaldi, Jufri, & Jamaluddin, 2020). Good learning media are those that can motivate students, provide meaningful learning experiences, and provide opportunities for analysis and individual performance (Sunaryo, 2021).

CONCLUSION

Based on the results of data analysis, it can be concluded that PhET interactive simulations are effectively implemented as virtual laboratories in science learning in elementary schools.

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