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Analysis of the Effectiveness of Guided Inquiry-Based Physics Learning with the PhET Simulation Guidebook on Global Warming Material

Efforts to Improve Science Process Skills of High School Students

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ABSTRACT

This research aims to develop a guided inquiry-based physics learning guidebook using PhET simulations on global warming material to improve the science process skills of 10th-grade students. The type of research used is development research with a 4D development model. However, this research was carried out only at the development stage, where the product being made would be tested for feasibility first by experts to find out how far the product had been developed. The subjects in this development research were two media experts and two material experts as validators of the guidebook being developed. The media and material expert validation results show that this guidebook falls within the criteria of being quite valid, with a percentage score of 45% from the media expert validation test and 46% from the material expert validation test. This guidebook can be considered a good development based on the development results. It can be used to support physics learning at the high school level, especially regarding global warming.

Introduction

The rapid development of technology impacts all aspects of life, one of which is education. In education, technological developments influence the use of learning media. Various learning media are developing and transforming into digital-based media. This digital-based learning media can be a learning management system or animation that depicts a simulation of learning concepts, especially in physics learning.

Learning physics is considered a complex subject, especially regarding global warming. Global warming material is a physical material with many applications in everyday life, especially environmental-related ones. Therefore, students must fully understand the symptoms, the impacts they cause, and the solutions that can be taken to overcome global warming. This can be obtained through learning. Indirectly, the environmental conditions around students affect the implementation of learning outcomes. Therefore, students must understand that every activity they carry out impacts the environment. PhET simulations can give students an idea of the earth's condition, where there are greenhouse gases, such as carbon dioxide, methane, and other elements. The industrial, agricultural, forestry, and other sectors that continue to grow are also the causes of global warming. Greenhouse effect gases cause heat from the earth that should be reflected to be trapped [1]. Overcoming the impact and preventing the greenhouse effect requires the involvement of various parties, including students. So, in the physics learning process, in warm-up material, learning media is needed to support practical or demonstration learning activities so that students can understand science concepts realistically.

Digital-based learning media have developed and played a role in the physics learning process, one of which is in the form of virtual laboratories. This virtual laboratory is interactive multimedia with a series of laboratory equipment in the form of (virtual) software, which is operated using (real) computer hardware and can carry out simulations like actual practical activities [2]. One virtual laboratory used globally is the PhET simulation, developed by the University of Colorado. According to [3], PhET learning media contains physics material simulations to benefit class or individual learning. PhET's flexibility makes it a portable simulation because it can be accessed using various devices. PhET provides interactive animation-based simulations of various Physics, Chemistry, Biology, Mathematics, and Earth Science learning materials, allowing students to interact and explore their understanding of global warming material through these simulations. PhET can also connect concepts and real phenomena that occur and provide a visual depiction of phenomena that are difficult for students to observe directly [4].

Research conducted by [5] examined physics learning outcomes in dynamic electrical material assisted by PhET simulations, which can improve student learning outcomes. Ref. [6] also found that students were more interested and motivated to learn by using PhET Software media and were able to build good communication between teachers and students and vice versa. The results of research by [7], [8] revealed an influence and improvement after using the PhET simulation through a guided inquiry approach to critical thinking skills, in line with [8], who also revealed that by using PhET media and the guided inquiry model, students' understanding of concepts and interest in learning physics is better. This is also comparable to research [9], which shows that implementing the guided inquiry model can improve student learning outcomes. However, from the research that has been conducted, there needs to be more information to understand the material presented in a form that does not attract students' attention. Then, some students still need help understanding how to relate the material studied to the PhET simulation.

Based on this explanation, teachers must also apply appropriate learning models apart from implementing learning media. Teachers can create a more interactive and interesting learning environment by combining the right media and learning models. So, the author is interested in developing a learning tool with a guided inquiry model in the form of a PhET simulation guidebook on global warming material for the 10th-grade students.

In this case, the guided inquiry learning model is the appropriate learning model to help students simulate PhET on global warming material. According to [10], the advantage of the guided inquiry model is that it emphasizes the development of cognitive, affective, and psychomotor aspects in a balanced way so that learning through this strategy is considered more meaningful. The guided inquiry model is very suitable if learning is combined with PhET media because it can help students learn physics concepts, and the PhET display can attract students' attention.

Learning with PhET simulations combined with Inquiry Learning produces a deeper and more meaningful learning experience for students. Various learning theories support this approach, highlighting active engagement, practical experience, and integrating science concepts [7], [9]. PhET simulations provide students with the opportunity to be actively involved in learning. Students can explore and test science concepts in real-time by providing an interactive virtual environment [4]. This approach is based on the principles of constructivism, which emphasizes that effective learning occurs when students actively build their knowledge.

Method

This type of research is Research and Development, with a 4D development model consisting of 4 research procedures: define, design, develop, and disseminate. However, this research is only up to the development stage. Expert validation data collection using the Delphi technique will be conducted during December 2023. The data is collected directly after the validation test is completed. The subjects in the development of this research are two media experts and two material experts as validators of the guidebook developed.

The instruments used in the validation test by experts consist of instruments assessed from five aspects of assessment with various items, namely general display (five items), unique display (six items), presentation of PhET media through guidebooks (two items), material in general (six items), presentation of material specifically (five items), and interactivity between students (two items). The rating scale used in expert assessment instruments includes four levels of the Likert scale, starting from very invalid, given a score of one, to very valid, given a score of five. The validation result from the validator is calculated as a percentage.

According to [11], the learning tools developed are feasible if they are on the criteria of quite valid, valid, and very valid, as seen in Table 1. They are learning device validation criteria. Analysis of the effectiveness of learning tools is calculated by a normalized gain test (N-gain score), which aims to determine the effectiveness of the guidebook on global warming material with the guided inquiry model used. The average N-gain score results are further categorized as improvement in science process skills and mastery of concepts, including low, medium, or high categories, as seen in Table 3—n-gain score division category. The average N-gain results obtained are further categorized as the level of effectiveness. According to [12], learning tools are practical if they are at a percentage of 56%-57% with a reasonably practical category and at a rate of more than 76% with an effective category; meanwhile, if it is at a percentage of less than 40 including ineffective and 40%-55% is said to be less effective.

Results and Discussion

A. Handbook development

Fig. 1 shows the cover of the book and some of the contents of the PhET simulation book guide on global warming material. The contextual teaching and learning approach is employed in developing the PhET simulation book guide on global warming material. Cases encountered while running the simulation application are related to everyday occurrences that students can identify with. In this way, it is hoped that this learning experience can be relevant for students and foster the development of insights and knowledge in physics.

The contextual teaching and learning approach emphasizes the connection between subject matter and real-life or contextual situations in the students' lives [13]. In developing

the PhET simulation guide on global warming, this approach makes learning more relevant and engaging for students. By linking cases from running the simulation application to everyday events that students can relate to, this learning is expected to be more easily understood and applicable [14], [15]. For example, there might be a simulation on temperature changes in the environment, and the cases selected could be related to the effects of global warming on weather, climate patterns, or its impact on daily life.

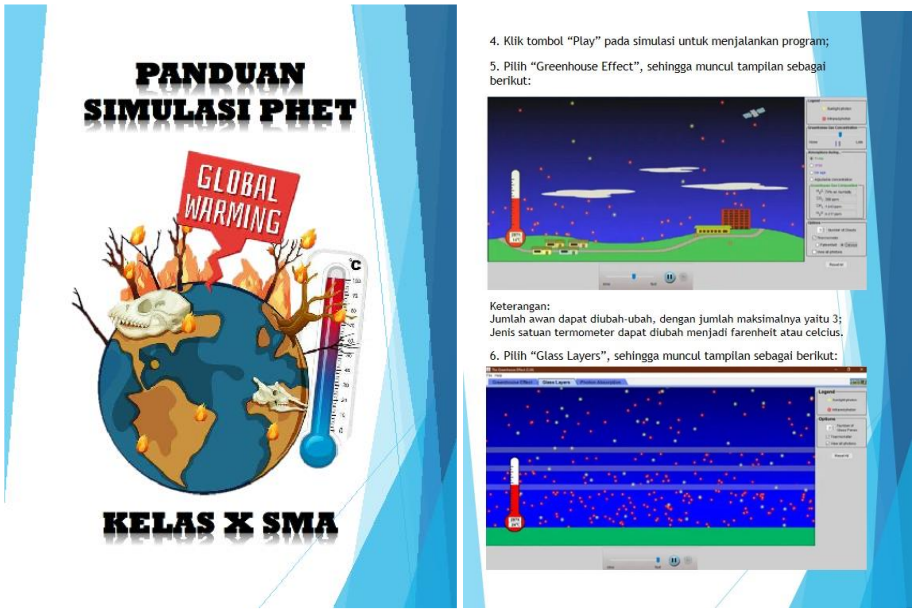

Fig. 1. Book cover and contents of the PhET simulation book guide

This approach can help students see the relevance of physics concepts to natural phenomena they experience, thereby enhancing their understanding of the material. Moreover, it is hoped that it will motivate students to learn, as they can see how physics concepts can be applied in their day-to-day lives [16]. Hopefully, using the contextual teaching and learning approach will create a more meaningful learning experience and assist students in developing practical insights and knowledge in physics.

B. The effectiveness of the guidebook

Based on the results of the media expert validation test, the media feasibility validity data has been validated by the Physics Education Lecturer at Ahmad Dahlan University, with the score obtained at the validity value of ±4.54 with a percentage of 30% so that the media for developing phet simulations on global warming material is in the medium category.

Based on the material expert validation test results, the guidebook showed moderate effectiveness, with an overall average score of 4.54 and 4.62 from media experts and material experts, respectively. The guidebook can be considered successful in supporting physics learning by being exciting and contextual and facilitating learner understanding and

interaction. However, in the development of this guidebook, there are still several things that researchers must improve, such as the material in the module that must be completed and by the simulation, language spelling that students easily understand, and the completeness of procedures for using simulation features.

Learning with PhET simulation integrated with Inquiry Learning results in a more immersive and meaningful learning experience for students. Various learning theories support this approach, highlighting active engagement, practical experience, and integrating science concepts [14], [17], [18]. PhET simulations provide opportunities for students to be actively involved in learning. Students can explore and test science concepts in real-time by providing an interactive virtual environment [14]. This approach is in keeping with the principles of constructivism, which emphasizes that effective learning occurs when students actively build their knowledge.

Integrating Inquiry Learning in this combination enhances students' learning by applying the scientific method. Students are encouraged to formulate questions, plan experiments, collect data, and evaluate results [19], [20]. PhET simulations provide powerful tools to support these steps virtually, creating an environment that facilitates an in-depth understanding of science concepts. The interrelationships between science concepts can be better understood using PhET simulations. Students can directly observe the effects of variable changes, supporting constructivism and cognitivism theories that emphasize the importance of relationships between knowledge.

Student motivation is also enhanced through PhET simulations, which present exciting and relevant learning. Students' intrinsic interest can increase because they can investigate independently and see the immediate impact of their decisions [21], [22]. In addition, PhET simulations allow students to learn from their mistakes. By creating diverse scenarios, students can identify errors and design solutions according to the principles of constructivism [21], [23], [24]. Combining Learning with PhET Simulation and Inquiry Learning creates an interactive, challenging, and relevant environment. It describes a learning approach that accommodates a variety of learning theories to enhance students' science skills holistically.

Conclusion

Based on the study results, it can be concluded that learning tools like physics manuals on global warming material and guided inquiry models assisted by PhET simulations are feasible with valid and effective criteria to improve science process skills. However, the results obtained with the moderate category or improvement are not too significant. Thus, this guidebook can be considered a learning tool that is entirely valid and able to improve the science process skills of learners adequately. Therefore, this development can be an excellent

alternative to support physics learning at the high school level, especially in the context of global warming material.

Conflict of Interest

The authors declare that there is no conflict of interest.

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