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Enhancing Science Learning Outcomes: The Impact of Discovery Learning Model Assisted by PhET Simulations

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Abstract

This study investigates the efficacy of integrating PhET Simulations (Physics Education Technology) into the discovery learning model to enhance science learning outcomes among fourth-grade students at MIS Daarul Qolam Kabupaten Bandung. Recognizing the importance of active student engagement in the learning process, the discovery learning model empowers students to explore and uncover scientific concepts independently. However, to optimize this approach, effective and engaging instructional media are essential. PhET Simulations offer virtual environments that facilitate a deeper understanding of scientific principles, making them a promising tool for enhancing learning experiences.

Employing a pre-experimental method with a one-group pretest-posttest design, the study involved 28 fourth-grade students. Data collection comprised written tests featuring multiple-choice questions. Analysis of the results, including hypothesis testing using the t-test, revealed a significant improvement in student learning outcomes. The calculated t-value (11.44) exceeded the critical t-value (2.11), indicating a rejection of the null hypothesis. Additionally, the N-gain test yielded a moderate criterion value of 0.62, affirming the positive impact of integrating PhET Simulations into the discovery learning model.

These findings underscore the effectiveness of utilizing PhET Simulations to augment the discovery learning approach in enhancing science education at the elementary level. The study suggests the adoption of this innovative pedagogical approach and recommends further research to explore its application across diverse learning contexts and subject areas.

Keywords: Discovery Learning, PhET Simulations, Learning Outcomes, Science Education, Elementary Education, Active Learning

Introduction

Learning natural sciences in elementary schools becomes a place for students to find and develop various potentials and skills in students. Through science learning, students gain a variety of new knowledge. However, it is possible that students also have other knowledge, which is formed through experiences they gain outside of school. Science learning using the constructivism model can be used to help students understand the relationship between teaching materials and the problems they encounter in everyday life. Therefore, the constructivist view pays attention to and considers students' initial knowledge that may be obtained outside of school (Stiawan, 2016). Science learning using the constructivism learning model is considered the most appropriate to the characteristics of science learning. Based on several opinions regarding the constructivism approach, it is stated that the constructivism approach is one of da's views in the learning process. The constructivism approach assumes that the learning process begins with the knowledge and experience that students already have to build their own knowledge. However, prior knowledge and experience possessed by students, often lead to misconceptions resulting in cognitive conflict within students. This cognitive conflict occurs when there is a discrepancy between new knowledge and prior knowledge possessed by students. To overcome cognitive conflict, learning activities should be able to show the relationship between material and real experience so that students can receive new knowledge to have a better understanding of concepts. (Jatisunda, 2017; Saud, 2017; Stiawan, 2016).

Through the constructivism approach in learning science, students can understand the relationship between learning concepts and the problems they encounter in everyday life. Constructivism approach encourages students to build their own knowledge in understanding the concept of learning. Students' understanding of concepts will affect student learning outcomes. Learning outcomes can provide an overview of changes in student behavior (Purwanto, 2013); which is a benchmark for knowing the level of student understanding in the learning process (Farid et al., 2018). Therefore, in the learning process the teacher should provide opportunities for students to learn actively in discovering learning concepts, so that students have a better level of understanding, especially in the cognitive domain.

Based on the results of a survey conducted by Trends In International Mathematics and Science Study (TIMSS) 2015, it was shown that the ability of science in the cognitive domain of grade IV elementary school students in Indonesia earned a score of 397 points (Mullis et al., 2016). This shows that students' understanding of science concepts is not optimal, though understanding science concepts is very important to form human resources who have the knowledge and skills that are in accordance with the development of science and technology.

This, in line with the results of initial observations made in class IV MIS Daarul Qolam, it is known that the minimum completeness criterion score set is 75. Data on science scores obtained by class IV students shows that students' scores on science content are still low. Of the 28 students in grade IV, there were only 6 students or around 33% of students who had achieved the KKM. Whereas 12 students or as many as 67% of students still scored below the KKM that had been set, namely 75. This caused students to need remedial activities to be able to improve the value of learning science. In relation to the science learning process carried out in class IV MIS Daarul Qolam Bandung Regency, the use of learning models and media has not been adapted to the teaching materials. The learning model commonly used in science learning is the conventional model, using lecture and question and answer methods.

Meanwhile, the use of learning media that is relevant to teaching materials is still very limited. The use of learning models that are not varied can place students as passive learners. So that students are used to learning by relying only on the teacher as the only source of learning, to obtain information related to teaching materials. In addition, the lack of use of learning media makes students feel bored and do not understand the learning material. The use of learning models that are less varied and the lack of use of learning media are obstacles in the science learning process in class IV. This is what causes students experience difficulties in understanding the concept of learning, so that it has an impact on the low learning outcomes obtained by students in learning science.

To improve the quality of science learning, we need a learning model that is relevant to the needs of students and learning materials. Although there are other factors that can affect student learning outcomes, the use of constructivism learning models can help students overcome cognitive conflicts, so that students can have a better understanding of concepts to improve learning outcomes optimally. Discovery learning learning model is a learning model that adheres to constructivism. The discovery learning model is an essential learning model in science learning (Wisudawati & Sulistyowati, 2014); which is able to involve the active role of students in seeking and discovering a learning concept through observation or experiment.

Based on several opinions, it is stated that the discovery model learning can be interpreted as a learning model that allows students to learn independently by searching for and finding learning concepts, through problems that have been engineered by the teacher. In other words, the application of this discovery learning model is carried out by students with there are directions given by the teacher who acts as a learning facilitator. So that in the learning process, the teacher does not convey the material as a whole, but encourages students to identify what they want to know, seek information from various sources and then form their own learning concepts based on what they know and understand (Ali, 2004; Fadriati, 2017; Farid et al., 2018).

The discovery learning model has characteristics that are in accordance with science learning. Therefore, in science learning students learn the relationship between humans and nature through a process of observing and collecting natural concepts that are logical and systematic which direct students to activities discovery learning (Ariyanto, 2018). Several studies have shown that the application of the discovery learning model in science learning can improve students' cognitive abilities and process skills (Ratnaningsih et al., 2017); and able to increase the effectiveness and student learning outcomes (Rosdiana et al., 2017).

The use of discovery learning learning models is important to be implemented in science learning with learning objectives that lead to the process. The process here is themed with practical activities. Through practicum activities, students not only accept but also try, train, develop and find their own learning concepts. However, practicum activities in the discovery learning learning model are more directed to virtual practicum. Virtual practicum activities are relatively easier, cheaper and can encourage student learning motivation in understanding learning concepts to become more real, specific, and easy to understand (Nugroho, 2021). Therefore, virtual practicum activities are able to visually present learning concepts that are interactive, dynamic, animative and not boring (Hendra, 2012); as well as being able to provide a safe and fun learning experience so as to support learning activities (Arif, 2019).

The discovery learning model that emphasizes the process of discovering learning concepts requires a medium that is able to provide opportunities for students to be able to carry out observational and experimental activities. PhET Simulations is an interactive simulation media that allows students to carry out practical activities in learning science. This is in accordance with the statement of Perkins et al., (2006) that "The Physics Education Technology (PhET) project creates useful simulations for teaching and learning physics and makes them freely available from the PhET website http://phet.colorado.edu. The simulations are animated, interactive, and game like environments in which students learn through exploration". Pernyataan tersebut dapat dimaknai, bahwa PhET (Physics Education Technology) is a simulation created to help students and teachers in the process of learning science (physics, chemistry, and biology), which is designed in such a way that it looks attractive and is open to all students doing experiments through the animations contained in PhET Simulations.

PhET Simulations provides a variety of interactive simulations that allow students to carry out observational and experimental activities, to find a learning concept about scientific phenomena that are usually difficult to observe. This is in accordance with the opinion of Finkelstein et al., (2006) that "The simulations seek to build explicit bridges between students' everyday understanding of the world and the underlying physical principles". Thus, the use of PhET Simulations in science learning can help students build and understand learning concepts better. This is evidenced by the results of a survey by Bandoy et al. (2016), which shows that the majority of respondents agree that PhET Simulations help them to learn concepts, improve problem solving skills, and motivate them to learn science concepts. Several other studies have shown that the use of PhET Simulations can improve students' psychomotor skills (A. Sujana et al., 2012); provide a better representation of learning (Kukkonen et al., 2014); and able to improve student learning outcomes (Ekawati et al., 2015). Thus, the use of PhET Simulations in the science learning process is highly recommended to improve the quality of education by utilizing technology, to create effective, student-centered learning and provide positive learning experiences to students. Discovery learning emphasizes the process of discovering a concept or principle that was previously unknown (Prayitno, 2017). Therefore, the process of discovering these concepts can utilize PhET Simulations as a simulation medium in virtual practicum activities, which can present scientific phenomena related to real problems in everyday life (Perdana et al., 2017), so that students can understand learning concepts that are difficult to observe directly (Arsyad, 2017). The application of the discovery learning model assisted by PhET Simulations has six stages, namely: (1) Simulations (2) Problem Statements (3) Data Collections; (4) Data Processing; (5) verification; and (6) Generalizations. As for the use of PhET Simulations in learning, it is used at the data collection stage, to help students discover science learning concepts that are relevant to the 2013 Curriculum teaching materials in grade IV SD. The material used in this research is energy changes contained in Theme 2; Always Save Energy, Sub Theme 1; Energy sources.

The use of PhET Simulations as a virtual simulation medium is able to provide real illustrations, in the form of interactive simulations that present various research-based physical phenomena that can be used free of charge and practically. The use of PhET Simulations can also be run using Android via the latest version of Google Chrome. The PhET Simulations media has a system design that allows students to carry out interactive activities in trying and directly observing physical phenomena, so that students can discover and understand learning concepts. The design of the PhET Simulations system on energy matters and changes in energy

forms are as follows. (a) Energy sources, in the form of water energy, sunlight energy, steam energy, and motion energy which is depicted by a person pedaling a bicycle; (b) Converts the form of energy, in the form of driving turbines and solar panels to transmit energy;

(c) The use of forms of energy, as a result of changes from one form of energy to another form of energy, which is indicated by changes in the temperature of the water, the lights shining, and the movement of the windmills.

The use of PhET Simulations on energy sources and their changes is accompanied by an explanation of the learning objectives that can be achieved by students. The learning objectives of PhET Simulations in energy forms and changes simulations are to help students to; (1) explaining various types of energy and examples in everyday life, (2) explaining how energy can change from one form to another, and (3) explaining how energy flows so that it can change one form of energy to another. Science learning using the discovery learning model assisted by PhET Simulations can create a fun learning atmosphere by providing different learning experiences to help students understand the whole learning concept for a long time, because in the learning process the teacher acts as a facilitator who encourages and directs students to be involved active in observations and experiments to find a concept for themselves through PhET Simulations.

Thus, the use of the discovery learning model assisted by PhET Simulations (Physics Education Technology), is able to increase student learning interest in building learning concepts independently, and can develop science process skills in students. Several studies have shown that the use of PhET Simulations-assisted discovery learning models can improve student achievement (Hariyanto et al., 2016); able to improve science knowledge competence (Putri et al., 2018); and able to increase students' understanding of concepts (Nurulhidayah et al., 2020). Therefore, the use of the discovery learning model assisted by the PhET Simulations simulation program can have a positive influence, which is able to increase the effectiveness of science learning, which is marked by an increase in various student abilities, especially in the cognitive domain. Referring to the description above, the researcher is interested in knowing "is there any effect of using the PhET Simulations-assisted discovery learning model on student learning outcomes?".

Research methods

This study uses a quantitative approach, with the Pre-Experimental research method. According to Sugiyono (2017) pre-experimental research is a design that only involves one group or one class that will be given a pre- and post-test. As for The design form used in this study is the One Group Pretest-Posttest Design, which can be described as follows.

Tabel 1. Desain Penelitian

Pretest	Treatment	Posttest
O1	X	O2

(Sugiyono; 2017)

This study used the One Group Pretest-Posttest Design so that there was only one study group, namely fourth grade elementary school students. The study group received a pre-test given to students before being given treatment and got a post-test given to students after receiving

treatment using the discovery learning model assisted by PhET Simulations in science learning. The use of the pre-test and post-test in this study was carried out to compare the results of the tests before and after the treatment was given to the study group.

The location of the research was carried out at MIS Darul Qolam, Bandung Regency. Given that this research was carried out during the COVID-19 pandemic, the research was carried out in limited face-to-face situations while still observing and implementing health protocols. The subjects in this study were 28 students of class IV MIS Darrul Qolam Bandung Regency. The study group received treatment using the discovery learning model assisted by PhET Simulations in the natural science content contained in Theme 2; Always Save Energy, Sub Theme 1; Energy sources. The treatment is carried out by utilizing virtual simulation media to understand the learning material contained in the theme, namely energy sources, energy changes and alternative energy and their utilization.

The data collection technique used a written test in the form of multiple choice questions of 40 questions consisting of 20 pre-test questions and 20 posttest questions. The validity of the instrument uses Pearson Product Moment while the reliability of the instrument uses Kuder-Richardson (KR20). In addition, this instrument has also passed the content validity of the expert judgment, namely one science teaching expert lecturer and one evaluation expert lecturer learning. Furthermore, the results of the pre-post test were analyzed using chi squared to determine normal or abnormal data distribution as a prerequisite analysis test that determines the next data analysis technique. The data analysis technique uses the t test, with the paired sample t-test technique. The hypothesis put forward in this study is "There is an effect of using the discovery learning model assisted by PhET Simulations on student learning outcomes." In addition, in this study there is an NGain Test to find out how much student learning outcomes have increased, after being given treatment using the PhET Simulations-assisted discovery learning model using the N-Gain formula as follows.

$$N - gain = \frac{S\ post - S\ pre}{S\ maks - Spre}$$

(Arikunto, 2015) Ket:

Spost = Nilai post-test

Spre = Nilai pre-test

Smaks = Nilai maksimum ideal

Research results and discussion

Research result

This research is a pre-experimental study using a one group pretest-posttest design. So that data collection in this study was carried out by pre-test and posttest, using a written test in the form of multiple choices. The pre-test and post-test administration in this study aims to determine how much influence the use of the PhET Simulations-assisted discovery learning model has on student learning outcomes.

Giving pre-test in this study using multiple choice questions, as many as 20 questions. The purpose of giving this pre test is to find out the extent of students' initial abilities before being given treatment in learning using the discovery learning model assisted by PhET Simulations. Based on the results of pre-test data processing, the data obtained from the initial student test results are as follows.

Tabel 2. Data Nilai *Pre-Test*

Data	N	Nilai Terendah	Nilai Tertinggi	Jumlah Nilai	Mean	Standar Deviasi
Pretest	28	30	70	855	47,50	11,53

Based on the table it is known that the pretest value data with a total of 18 grade IV students obtained the lowest score of 30 and the highest score of 70. The total score obtained was 855, the average pretest score was 47.50 and the standard deviation was 11.53.

Furthermore, the implementation of the post-test in this study was carried out using a written test in the form of multiple choice questions of 20 items. The purpose of giving this post-test is to find out how far the students' final abilities are after being given treatment in learning using the discovery learning model assisted by PhET Simulations. Based on the results of processing the post test data, the data obtained from the post test results of the students are as follows.

Tabel 3. Data Nilai *Post Test*

Data	N	Nilai Terendah	Nilai Tertinggi	Jumlah Nilai	Mean	Standar Deviasi
Posttest	8	70	90	1450	80,56	6,84

Based on the table above, it is known that the results of the post-test on 18 grade IV students obtained the lowest score of 70 and the highest score of 90 with a total score of 1450. The average score obtained by students was 80.56 and the standard deviation of the post-test score was 6,84. The data recap of student prepost test results will be described as follows.

Tabel 4. Data Nilai Pre-Post Test Siswa

Data	N	Nilai Terendah	Nilai Tertinggi	Mean
Pretest	18	30	70	47,50
Posttest	18	70	90	80,56

Referring to the table, it is known that the pre-posttest value data from 18 fourth grade students of elementary school, shows that the pre-test results obtained a total score of 855, the lowest score was 30, the highest score was 70 with an average score of 47.50. While the post-test results obtained a total score of 1450, the lowest value was 70, the highest value was 90 with an average value of 80.56. The value data shows that the post-test scores obtained by students are better when compared to the pre-test scores obtained by students before receiving treatment using the PhET Simulations-assisted discovery learning model.

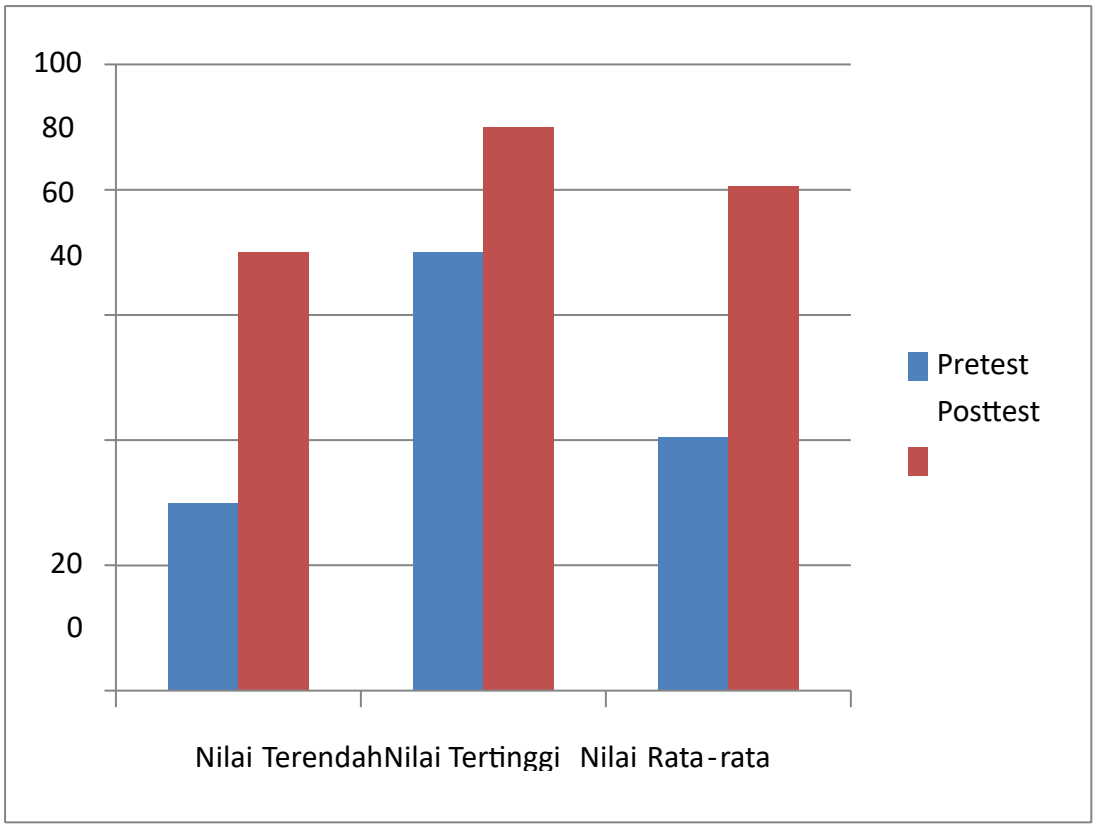
Furthermore, the pre-post test data is tested for normality as a prerequisite analysis test that determines the next data analysis technique. The pre-post test data normality test is calculated using the Chi Square formula (X2) with a significant level of $\alpha = 0.05$. Based on the results of the normality test it is known that the pretest data obtained Xcount (3.80) < X table (5.99) and the preposttest data obtained obtain Xcount (4.96) < X table (5.99) meaning that the data is normally distributed, so hypothesis testing can be continued using the t test formula. The results of the hypothesis test show that tcount (11.44) > ttable (2.11) which indicates that H0 is rejected, meaning that there is a difference before and after treatment. So that the hypothesis that reads "There is an effect of using the discovery learning model assisted by PhET Simulations on student learning outcomes" can be accepted. Then the results of the N-Gain test show that the value obtained by students is 0.62, meaning that there is an increase in learning outcomes that are in the Moderate criteria This shows that there is an increase in student learning outcomes after learning using the PhET Simulations-assisted discovery learning model in Science content in Theme 2, Sub-Theme 1.

Discussion of Research Results

The purpose of this study was to determine the effect of using discovery learning models assisted by PhET Simulations on student learning outcomes. So to be able to find out the effect of using the learning model, students are given a prepost test. The pre-test is given before the treatment is given in learning, to find out the extent of students' initial abilities. While the post-test is given after the treatment is given in learning, to find out the difference in student learning outcomes before and after learning using the discovery learning model assisted by PhET Simulations.

This research was conducted on students of class IV MIS Darrul Qolam

28 students. Learning activities begin by giving pre-tests to students, then giving treatment in learning activities using the discovery learning model assisted by PhET Simulations, and learning activities end by giving post-tests to students. Based on the results of data processing, data was obtained which showed that there were differences in student learning outcomes after learning using the PhET Simulations-assisted discovery learning model. This can be seen from the results of the initial tests (pre-test) and final tests (post-test) on 28 grade IV students of MIS Darrul Qolam Bandung Regency in the 2022/2023 academic year, as follows.



Graph 1. Students' Pre-Post Test Scores

Based on the students' pre-test and post-test score diagrams, it is known that the data from the pre-test results obtained the lowest score of 30 and the highest score of 70, with an average of 47.50. Meanwhile, the post-test results obtained the lowest score of 70 and the highest score of 90, with an average score of 80.56. The difference in the average pre-test and post-test scores shows that the use of the PhET Simulations-assisted discovery learning model has an impact on students' understanding of concepts so that student learning outcomes before and after being given treatment have a different average with a difference in value of 33.

The difference in student learning outcomes shows that students' understanding of concepts is better after learning using the PhET Simulationsassisted discovery learning model, in the matter of energy and its changes contained in Theme 2 Sub-Theme 1. The application of the PhET Simulationsassisted discovery learning model has six stages, namely: (1) Stimulation

(2) Problem presentation (3) Data collection; (4) Data processing; (5) Verification; and (6) Generalization. As for the use of PhET Simulations in learning, it is used at the data collection stage, to help students discover learning concepts. This is in line with the opinion of Kukkonen et al., (2014) that "simulation based inquiry leads pupils to generate their own data through experimentation and produce 'partial subject matter' which can form the basis of good conceptual, procedural and situational knowledge". This statement means that the use of simulation in the discovery learning process can produce a concept, which becomes the basis for better conceptual, procedural, and situational knowledge based on the results of experiments that have been carried out by students.

PhET Simulations provide visualizations that help students have a better representation of learning. Through interactive simulations, students can directly try, observe and know the energy changes that occur during experimental activities more objectively. The student-oriented constructivism learning process certainly has an impact on the level of students' understanding of learning concepts. This is in line with Mcelhaney et al., (2015) who explained that"Dynamic visualisations can help students link multiple representations. Dynamic visualisations enable students to conduct virtual experiments about complex situations and can include various supports for experimentation such as providing records of trials". So that the use of the discovery learning model assisted by PhET Simulations as an interactive medium, can connect students' ideas with real life that students encounter in everyday life by presenting scientific phenomena contained in PhET Simulations. Thus, the use of discovery learning models assisted by PhET Simulations, is able to increase the effectiveness of science learning

The application of the discovery learning model assisted by PhET Simulations is an alternative in science learning, which is able to create studentcentered learning, and is able to involve students in an active constructive role; interesting and easy to implement so that it will facilitate student understanding (Ekawati et al., 2015). In relation to the implementation of research, learning activities using discovery learning models assisted by PhET Simulations are carried out with direct supervision and direction from researchers who act as learning facilitators, so that learning activities can take place in a conducive manner. Learning activities are carried out in a manner in groups, using smartphones brought by students. Then, to make it easier for students to find learning concepts, each group gets a Student Worksheet, as a guide for discovery activities using PhET Simulations.

The development of students when learning using the discovery learning model assisted by PhET Simulations experienced significant changes, especially in conducting experiments and observations using PhET Simulations. Experimental activities using PhET Simulations in this study were carried out to help students discover the concept of energy sources and their changes. The following is an overview of students' understanding during the learning process using PhET Simulations.

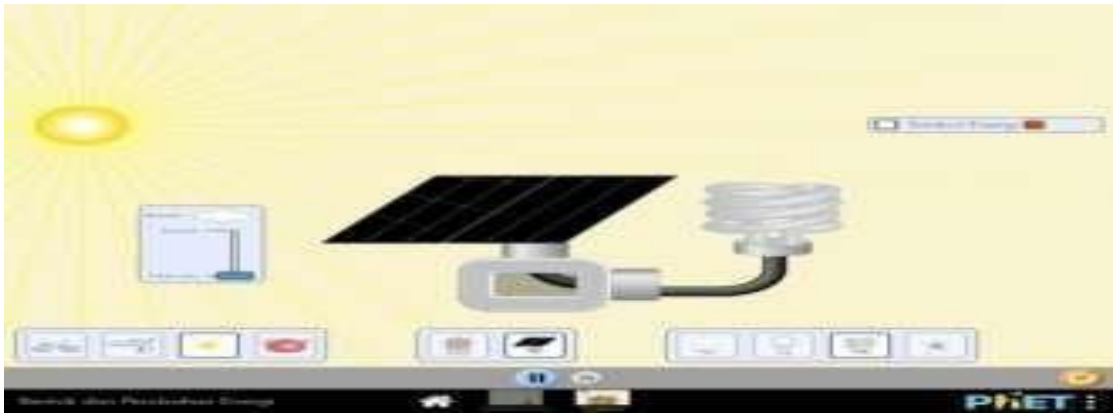


Figure 1. PhET Simulations Material 1

Figure 1. PhET Simulations Material 2

In Figure 1 you can see that PhET Simulations presents an interesting visualization like a game that can increase students' curiosity to use it. Students are given the opportunity to determine the energy source, the appropriate energy converter and what energy changes they want to observe. Then in Figure 2 it shows that students are conducting experiments regarding solar energy sources as alternative energy. The simple operation of PhET Simulations makes it easier for students to make discoveries. So that students can observe and explain how energy flows and converts one form of energy into another form of energy, based on the results of the observations they have made. Through this discovery, students have a good understanding to build learning concepts about energy and its changes in everyday life.

The use of the discovery learning model assisted by PhET Simulations is able to encourage active students to build their own knowledge in the learning process, so that students have a better understanding of concepts. This is evidenced by the results of testing the hypothesis using the t test which shows that tcount (11.44) > ttable (2.11), meaning that there is an effect of using the discovery learning model assisted by PhET Simulations on student learning outcomes. In addition, the N-Gain test results obtained a value of 0.62, meaning that there was an increase in the moderate criteria. The results of data analysis in this study showed that there was an increase in learning outcomes after students learned using the PhET Simulations-assisted discovery learning model.

Similar findings were shown by the research of Zahara et al., (2015) which showed that the experimental class that used PhET Simulations experienced a higher increase in learning outcomes than the control class that used learning conventional. In addition, research by Farid et al., (2018) showed that the improvement in learning outcomes in the experimental group taught using the PhET Simulations application was better than the control group. Thus, the discovery learning model assisted by PhET Simulations (Physics Education Technology) is able to have a positive influence on student learning outcomes.

This study shows that the use of the PhET Simulations-assisted discovery learning model is able to have a significant influence on student learning outcomes in Natural Science content. However, the researcher realizes that there are still limitations in this study, including: This study only measures student learning outcomes in the cognitive domain using the form of

multiple choice questions (PG). The implementation of this research was only carried out in class IV MIS Darrul Qolam Bnadung Regency. In addition, this research was only conducted on natural science content (IPA) regarding materials Energy and its Changes contained in Theme 2, Sub-theme 1. Therefore, the conclusions obtained only apply to one content, namely the content of Natural Sciences.

Conclusion

Based on the results of data analysis and testing of the hypothesis of the research data, it shows that there are differences in the average value and there is an increase in learning outcomes students, after learning by using the discovery learning model assisted by PhET Simulations. Thus, it can be concluded that there is an effect of the use of PhET Simulations-assisted discovery learning on student learning outcomes, in Science content Theme 2 Sub Theme 1 in class IV MIS Darrul Qolam Bandung Regency.

The results of this study can be a source of reference regarding alternative learning models in learning science in elementary schools. Therefore, the use of the PhET Simulations-assisted discovery learning model is able to create learning activities that are active, efficient, and fun, so that students have different learning experiences in building and understanding learning concepts to obtain optimal learning results. In addition, this research can be used as input or material for consideration for future researchers who are interested in developing the use of discovery learning models assisted by PhET Simulations, to measure other research variables, especially in learning Natural Sciences (IPA) in elementary schools.

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