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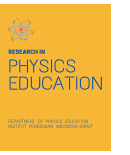

ARTICLE

The role of PHET-based virtual laboratories on primary students' motivation and conceptual understanding in the Energy Transformation concepts

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Abstract

This research was conducted based on the importance of motivation and understanding of concepts at the elementary school level. Learning with a PhET-based virtual laboratory is an innovative approach in science education that can help visualize abstract concepts. A quantitative descriptive method was chosen for this study, with a pre-experimental one-group pretest-posttest design. The sample consisted of fourth-grade students from public primary schools in Indonesia. The instruments used in this study were observation guidelines, questionnaires, and test questions. The results showed that the implementation of PhET-based virtual laboratory learning received an average score of 97.77%, which is considered very good. Motivation after learning with the PhET-based virtual laboratory had an average score of 71%, indicating a good level. Students' conceptual understanding increased after the implementation of PhET-based virtual laboratory learning, with the average pretest score rising from 55.8% to a posttest score of 77.2%.

Keywords: PhET-based virtual laboratory, students' motivation, conceptual understanding

1. Introduction

In carrying out the learning process, teachers must be selective and apply appropriate methods to enhance students' motivation and understanding of concepts (Arianti 2019). The rapid development of technology provides opportunities for teachers to use and leverage various computer animations to help students understand basic concepts or dynamic principles. Technology can simplify various needs in the teaching and learning process (Uno 2023). In educational institutions, technology is used as a supporting tool in the learning process, both as a means to access information about learning resources and as a support for learning and activities related to assignments given by teachers.

Currently, personal computers are widely owned by the public, and most educational institutions in Indonesia have provided computers as aids to support the learning process. Various problems typically encountered in laboratory learning include laboratory management issues, such as procurement, usage, and maintenance processes (Faradita 2021; Fatimah et al. 2020). To address these

problems, an innovation is needed. One form of innovation that can be used to solve these issues is the use of virtual apparatus in the form of interactive computer simulations (virtual laboratories) (Wiratma et al. 2014). Laboratories are used to illustrate various types of reactions that may not be visible in real life (Hermansyah, Gunawan, and Herayanti 2015).

Among the various virtual lab products available, one of the most accessible is the PhET Simulation Virtual Lab. PhET stands for Physics Education Technology and is produced by the University of Colorado at Boulder. PhET simulations can be freely accessed and downloaded for free, and can be used both online and offline. For effective learning, a good process and motivation are also required. This is why psychologists are beginning to focus on good motivation. The motivation that students consistently have determines their learning effort. In this context, motivation in the learning process becomes very important. Conceptual understanding is a behavioral process to comprehend abstract designs and ideas, which is acquired through learning (Dyrberg, Treusch, and Wiegand 2017). Conceptual understanding is the capacity obtained from experiences, facts, and events to create principles, laws, and theories without significant difficulty (Haug and Ødegaard 2014).

Learning that can foster learning motivation and conceptual understanding must start with a learning process that engages students actively. When students are actively involved in the learning process, their motivation to learn and conceptual understanding is expected to improve. Based on this background, a study titled "The Role of PhET-Based Virtual Laboratories on Student Motivation and Concept Understanding in the Subject of Energy Transformation" will be conducted.

2. Literature Framework

2.1 Virtual laboratory

A virtual laboratory is a software application that allows users to simulate specific laboratory experiences by replicating conventional laboratories into virtual ones. Generally, a laboratory is defined as a place where experiments and trials are conducted and analyzed (Faradita 2021). It is a simulation space for studying processes in a virtual world or social space, where scientists can interact, form groups, build relationships, and share views, ideas, resources, and work (El Kharki, Berrada, and Burgos 2021). In this virtual laboratory, students can see what happens on their computer through visual representations, animations, and real-life expressions adapted from the laboratory. This virtual laboratory allows students to explore, experiment, and learn in a safe and dynamic environment. Virtual laboratories have several advantages. One of these is the ability to implement an abstract concept that cannot be explained verbally. Virtual laboratories can be places where researchers conduct experiments that are not possible in traditional laboratories. One commonly used type of virtual laboratory is PhET. Within curriculum needs, there are several complex and abstract concepts that can be simulated and visualized to aid students' cognitive development (Ridlo, Indrawati, and Gani 2016). The concept of energy transformation requires visualization to help students understand the concept being studied. In the process of teaching science, specifically the topic of energy transformation, a PhET-based virtual laboratory is used. Students are expected to creatively explore the various components available in the simulation to achieve the learning objectives.

2.2 Students' motivation

Motivation originates from the Latin word "movere," which means to drive or move. Many experts express the concept of motivation from their own perspectives. Motivation is the drive to change behavior or perform certain activities better than before, through internal or external stimuli. Motivation is the basic drive that moves a person to behave in a certain way. The concept of learning motivation is the drive or enthusiasm that can transform students from having low to high desire to learn, whether this drive comes from external (extrinsic) or internal (intrinsic) sources (Faradita 2021). This drive manifests in individuals who are motivated to do something independently. Thus, a person's behavior based on certain motives aligns with the themes associated with those underlying

motives. The term motivation is an impulse that causes someone to take action to achieve a specific goal (Arianti 2019). In the context of learning, motivation is understood as the inner drive within students that prompts learning activities, ensures the continuity of learning, directs learning activities, and enables students to achieve their desired goals based on their objectives, needs, and desires. Furthermore, motivation in learning activities can be defined as any effort to motivate and inspire students, both stemming from the students' own conscience (intrinsic motivation).

2.3 Conceptual understanding

Understanding is the level of competence expected of students to comprehend concepts, situations, and known facts. Understanding refers to the ability to grasp and comprehend for the first time what someone knows or remembers, and the ability to interpret the meaning of the material learned (Rahmananda, Haryadi, and Darma 2024). Understanding is the ability to perceive the extent to which students receive, accept, and are able to understand the instructions given by their teachers. This conceptual understanding is an empirical abstraction. The place of a concept in scientific learning is part of a product that contains scientific facts. In another definition, conceptual understanding in a scientific context, according to experts, is the ability of students to comprehend the relationships between concepts so that they can be applied to problem-solving (Ramdani et al. 2021). Conceptual understanding is the ability to grasp meaning. For example, it involves understanding, providing, and applying interpretations to the material presented in a more comprehensible format. Poor conceptual understanding can be indicated by misinterpreting the meaning of content knowledge, definitions, and the justification of related knowledge (Russell and Martin 2023). When students' conceptual understanding is low, their understanding of other concepts will also be incorrect. Students who do not understand concepts well will find it difficult to grasp complex concepts, which will later become the foundation of their learning.

2.4 Energy transformation

Natural science, or science, encompasses a wide range of fields. Natural science as the study of the universe and its contents, along with natural phenomena, where experts conduct various scientific activities meticulously and carefully to develop it. Therefore, it is not surprising that when discussing science, the process always starts with deep thinking and preliminary observation to reach a conclusion. One of the subjects taught in elementary school science is energy transformation. Currently, energy is a basic human need. Almost every aspect of life requires energy to function. An object can perform work if it has sufficient energy. Energy is what makes an object operate. The largest source of energy is solar energy. The sun is the source of heat and light energy. The heat energy from sunlight brings many benefits to life on this planet. Without the sun, there would be no life on Earth. Without the sun, plants could not perform photosynthesis, and as a result, no plants would live. Besides solar energy, which is the largest energy source, this study only discusses several sources of energy such as heat energy, electrical energy, sound energy, and kinetic energy. Energy is invisible, but we can prove its existence when it causes something to move or change. For example, when a vehicle moves or a fan spins, we witness the presence of energy in these objects.

3. Research Method

3.1 Research design

The research design used in this study is a descriptive quantitative approach. Descriptive research is a method used to describe the results of a study (Millner, Robinaugh, and Nock 2020). Meanwhile, according to Subakti (2021), quantitative research is a method that investigates a specific population or sample. Descriptive quantitative research is a conscious and systematic effort to answer questions and obtain deeper and broader information about phenomena by using investigative steps with a quantitative approach. In this study, a pre-experimental One-Group Pretest-Posttest Design is

applied. In this research design, the first step is to conduct an initial test (pretest) before the treatment is administered. At the end, a final test (posttest) is conducted to determine the impact of the treatment administered. A single experimental class used in the study serves as the basis for using this design.

3.2 Participants and research instruments

The subjects in this study are students in the fourth grade of elementary school, specifically the sample from the study consists of fourth grade students from one public primary school in the west Java Province. Research instruments are tools for collecting research data to facilitate data processing and produce high-quality research. They function to obtain the necessary research data during the information-gathering phase in the field (Parpala and Lindblom-Ylänne 2012). The instruments used in this study are teacher observation forms, concept comprehension tests, and motivation questionnaires.

3.3 Data analysis

Data analysis involves systematically organizing the data obtained from the field. Data analysis techniques are methods for processing data and converting it into information. In quantitative research, data analysis is the activity undertaken after data has been collected from all respondents or other data sources. The quantitative research method can be defined as a research method based on the philosophy of positivism, used to study a specific population or sample (Anshori and Iswati 2019). Sampling is usually done randomly, using tools for data collection. The data analysis is quantitative/statistical in nature and aims to test hypotheses. The presentation of data in this descriptive quantitative analysis can be in the form of tables, graphs, diagrams, and so on. The presented data is then described. Descriptive statistics are used to analyze data by describing or illustrating the collected data as it is, without intending to draw general conclusions or generalizations. The presentation of data in this descriptive quantitative analysis can be in the form of tables, graphs, diagrams, and so on. The results of the presented data are then described.

4. Result of the research and discussion

4.1 PHET-based science learning in primary school

The implementation of teaching is a process where, after certain steps, the teaching is designed to achieve the expected outcomes. In conducting teaching, teachers go through several stages, such as opening the lesson, conducting activities, and closing the lesson. Based on the teacher's observations, the implementation of virtual laboratory learning using PhET on the topic of energy transformation achieved a percentage of 97.77%, which falls under the interpretation of being very good. It can be said that the teaching implementation was successful because it was carried out very well. During the teaching activities, the teacher applied a contextual approach using lecture, discussion, and question-and-answer methods. Parhan and Sutedja (2019) mention that teaching using a contextual approach is designed to combine knowledge and action in a more concrete, realistic, current, real, enjoyable, and meaningful way by discovering the essential meaning behind theoretical material. The average score for the ability to apply this teaching approach was 97.77%, with a very good interpretation. Meanwhile, the teacher's ability to master the teaching material and use teaching media each received an average of 100%, with both being interpreted as very good. Furthermore, the teacher's attitude during teaching activities also achieved an average of 100%, with a very good interpretation. Lastly, the teacher's ability to conduct evaluations received an average score of 100%, with a very good interpretation. This interpretation does not mean that students' scores must also be high, as this depends on the abilities of each individual student.

Table 1. Result of the PHET-Based science learning observation

No	Aspects	Score	Maximum score	Means
1	The opening of learning process	32	33	96.96 %
2	Attitudes in the learning process	12	12	100%
3	Mastering teaching materials	15	15	100%
4	Learning process	15	15	100%
5	Learning approaches	18	18	100%
6	The ability to use learning media	15	15	100%
7	Evaluating ability	15	15	100%
8	The ability to finish learning process	12	12	100%
Total score			133	
Means			97.77%	
Interpretation			Very good	

4.2 Student motivation

From the indicator of student attention in PhET-based virtual laboratory learning, the percentage is 71%. The first indicator shows a percentage of 82%, indicating that the strong willingness to participate in PhET-based virtual laboratory learning is very positive. The second indicator shows a result of 77%, suggesting that the amount of time students spend learning is positive. The third indicator is at 72%, which is positive. The fourth motivation indicator shows a percentage of 72%. The fifth indicator shows a percentage of 63%, indicating that students have a positive attitude towards facing difficulties in learning. The sixth indicator shows a percentage of 68%, indicating that students have a fairly positive interest in various adult issues. The seventh motivation indicator shows a percentage of 68%, meaning students are fairly positive about preferring to work independently. The final student motivation indicator shows a percentage of 69%, meaning students are fairly positive about maintaining their opinions during learning. The overall percentage of student motivation after the learning session is 71%, which is interpreted as positive. These results indicate that after PhET-based virtual laboratory learning, student motivation is positive. These findings align with the opinion expressed (Faradita 2021), which states that learning with virtual laboratory media can motivate students to learn, and with the help of virtual laboratory media, teachers can more effectively act as learning facilitators, making the learning process more effective and efficient.

Table 2. The result of questionnaire observation

Indicators	No	Real score	Ideal score	%	Interpretation
Strong interest to learn something	1, 2, 3	246	300	82	Very positive
Amount of time provided for learning	4, 5, 6	232	300	77	Positive
Willing to improve learning process	7, 8	144	200	72	Positive
Persistence doing homework	9, 10	144	200	72	Positive
Persistent in learning	11, 12, 13	190	300	63	Positive
Have interest to issues in the learning process	14, 14, 16	205	300	68	Positive
Happier to learn independently	17, 18	135	200	68	Positive
Remain arguments	19, 20	138	200	69	Positive
Total percentage				71	Positive

4.3 Conceptual understanding

After the data results are presented in Table 3, the next step involves conducting descriptive statistical tests to examine the detailed differences between the pretest and posttest results. The following are the results of the descriptive statistical tests. From these tests, it was found that the minimum pretest score was 20, the maximum score was 80, and the mean score was 55.80%. Following the implementation of the virtual laboratory learning based on PhET, the posttest results showed a minimum score of 55, a maximum score of 100, and a mean score of 77.20%. This indicates, as seen in Table 4, a substantial increase in the students' scores from the pretest to the posttest.

Table 3. The result of the pretest and posttest

Average score	Score (percent)
Pretest	55.8
Posttest	77.2

Table 4. The result of descriptive statistics

Scores	N	Range	Minimum	maximum	Mean	Std.	Variance
Pretest	25	60	20	80	55.8	15.322	305.86
posttest	25	55	45	100	77.2	12.754	195.51

Table 5. The result of normality test

Score	Shapiro-Wilk test	df	sig
Pretest	0.954	25	0.309
Posttest	0.942	25	0.169

Based on Table 5, the normality test results showed that the pretest value was 0.309 > 0.05, indicating that the data were normally distributed. Similarly, the posttest data yielded a result of 0.169 > 0.05, also indicating normal distribution. Consequently, the next step involves performing a Paired Sample t-test, as both pretest and posttest data are normally distributed. The following presents the results of the t-test for pretest and posttest data. According to the results of the Paired Sample t-test conducted using SPSS version 25, the significance (2-tailed) value was 0.000 < 0.05, leading to the rejection of the null hypothesis and the acceptance of the alternative hypothesis. This indicates a significant difference between the pretest and posttest results among the students. Based on the N-Gain test results, the average N-Gain value for the students was 0.493, which is interpreted as moderate. Therefore, it can be concluded that learning with PhET-based virtual laboratories on the topic of energy transformation has a moderate effect on improving students' conceptual understanding before and after engaging in the virtual laboratory learning activities on the energy transformation topic (Ramdani et al. 2021).

5. Conclusion

The conclusions based on the results of this study are as follows: The implementation of PhET-based virtual laboratory learning on the topic of energy transformation was highly successful, with an average total score of 97.77%, which is interpreted as excellent. Students' motivation towards PhET-based virtual laboratory learning was positive, with an average questionnaire score of 71%. The average conceptual understanding of students before the culture-based learning was 55.8%. However, after the intervention with PhET-based virtual laboratory learning, the average conceptual

understanding of students increased to 77.2%. According to the results of the Paired Sample t-test conducted using SPSS version 25, the significance (2-tailed) value was 0.000 < 0.05, leading to the rejection of the null hypothesis (Ho) and acceptance of the alternative hypothesis (H1). This indicates a significant difference between the pretest and posttest results among the students. Regarding the impact of PhET-based virtual laboratory learning, the normalized gain test results indicate that it had a moderate effect on improving students' conceptual understanding.

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References

Anshori, Muslich, and Sri Iswati. 2019. *Metodologi penelitian kuantitatif: edisi 1.* Airlangga University Press.

Arianti, Arianti. 2019. Peranan guru dalam meningkatkan motivasi belajar siswa. *Didaktika: Jurnal Kependidikan* 12 (2): 117–134.

Dyrberg, Nadia Rahbek, Alexander H Treusch, and Claudia Wiegand. 2017. Virtual laboratories in science education: students' motivation and experiences in two tertiary biology courses. *Journal of Biological Education* 51 (4): 358–374.

El Kharki, Khadija, Khalid Berrada, and Daniel Burgos. 2021. Design and implementation of a virtual laboratory for physics subjects in moroccan universities. *Sustainability* 13 (7): 3711.

Faradita, Meirza Nanda. 2021. *Motivasi belajar ipa melalui model pembelajaran course review horay.* Jakad Media Publishing.

Fatimah, Ziadatul, Dedi Riyan Rizaldi, A Wahab Jufri, and Jamaluddin Jamaluddin. 2020. Model inkuiri terbimbing berbantuan laboratorium virtual untuk meningkatkan keterampilan proses sains. *Jurnal Pendidikan, Sains, Geologi, dan Geofisika (GeoScienceEd Journal)* 1 (2).

Haug, Berit S, and Marianne Ødegaard. 2014. From words to concepts: focusing on word knowledge when teaching for conceptual understanding within an inquiry-based science setting. *Research in Science Education* 44:777–800.

Hermansyah, Hermansyah, Gunawan Gunawan, and Lovy Herayanti. 2015. Pengaruh penggunaan laboratorium virtual terhadap penguasaan konsep dan kemampuan berpikir kreatif siswa pada materi getaran dan gelombang. *Jurnal Pendidikan Fisika dan Teknologi* 1 (2): 97–102.

Millner, Alexander J, Donald J Robinaugh, and Matthew K Nock. 2020. Advancing the understanding of suicide: the need for formal theory and rigorous descriptive research. *Trends in cognitive sciences* 24 (9): 704–716.

Parpala, Anna, and Sari Lindblom-Ylänne. 2012. Using a research instrument for developing quality at the university. *Quality in Higher Education* 18 (3): 313–328.

Rahmananda, Tiara, Rahman Haryadi, and Yudi Darma. 2024. Kemampuan pemahaman matematis melalui inovasi video pembelajaran berbasis model problem based learning. *MATHEMA: JURNAL PENDIDIKAN MATEMATIKA* 6 (1): 90–102.

Ramdani, A, AW Jufri, G Gunawan, M Fahrurrozi, and M Yustiqvar. 2021. Analysis of students' critical thinking skills in terms of gender using science teaching materials based on the 5e learning cycle integrated with local wisdom. *Jurnal Pendidikan IPA Indonesia* 10 (2): 187–199.

Ridlo, Zainur Rasyid, Indrawati Indrawati, and Agus Abdul Gani. 2016. Pengembangan model pembelajaran pots (preconditioning, organizing, thinking, simulating) untuk pembelajaran fisika kuantum. *Jurnal Pembelajaran dan Pendidikan Sains* 1 (1): 86–92.

Russell, Tom, and Andrea K Martin. 2023. Learning to teach science. In *Handbook of research on science education,* 1162–1196. Routledge.

Uno, Hamzah B. 2023. *Teori motivasi dan pengukurannya: analisis di bidang pendidikan.* Bumi Aksara.

Wiratma, I Gusti Lanang, et al. 2014. Pengelolaan laboratorium kimia pada sma negeri di kota singaraja:(acuan pengembangan model panduan pengelolaan laboratorium kimia berbasis kearifan lokal tri sakti). *JPI (Jurnal Pendidikan Indonesia)* 3 (2).