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The Influence of the PhET Virtual Lab Assisted PBL Model on Energy Transformation Material on the Learning Motivation of Elementary School Students

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Abstract: The challenge faced in basic education is how to present learning materials so that they are interesting, relevant, and able to encourage students to be motivated to learn actively. This study aims to find out whether there is a difference and influence of the PhET Virtual Lab Assisted PBL Model on Energy Transformation Material on the Learning Motivation of SDN Triharjo State Elementary School Students. The methodology adopted is a Quantitative approach quasi-experimental. The analysis use normality test, homogeneity of variance test, independent sample, and paired sample t test. The results of the study that sig. independent sample test 0.00 < 0.05 (there's different with applying the PhET Virtual Lab of 44.09 and not applying the PhET Virtual Lab of 37.73) and sig. paired sample t test (H_0 is rejected). So, the PBL Model assisted by PhET Virtual Lab has a significant influence on students motivation which is higher compared to the PBL Model without the assistance of PhET Virtual Lab of Triharjo State Elementary School Students.

Keywords: Motivation; PBL model; Virtual lab PhET

Introduction

Basic education has a crucial role in building the foundation of students' knowledge and skills (Fathoni, 2024). The challenge faced in basic education is how to present learning materials so that they are interesting, relevant, and able to encourage students to be motivated to learn actively. Istiqomah et al. (2023) also stated that one of the challenges in basic education is how to present learning materials so that they are interesting and relevant. An interesting and fun learning environment can encourage students to learn actively (Utomo, 2023). Scientific material, especially energy transformation, is often considered abstract and difficult to understand, this is because it involves abstract concepts, such as force, power and electromagnetic radiation. There is a need for innovative teaching methods that can facilitate student understanding and motivate students to learn.

Learning motivation reflects internal and external drives which ultimately influence their academic achievements (Filgona et al., 2020). Students' learning motivation will have an impact on the achievements achieved (Purnama et al., 2019). Without adequate motivation, students tend to be less enthusiastic and have difficulty achieving targets (Wahyuni, 2020). Understanding and developing learning motivation is very important in the educational context (Palittin et al., 2019; Wahyuni, 2020). Student learning motivation will influence the student learning outcomes obtained. If students have good learning motivation, learning outcomes will also be good, so learning motivation is stated as one of the learning outcome factors (Erlitaviana & Tyas, 2025). Many factors influence student learning motivation, both from individual and environmental aspects.

Individual factors such as interest, self-confidence, and clear learning goals in understanding the subject matter (Ballane, 2019). This factor comes from within the

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student which is the main factor needed to have the motivation to study the surrounding natural conditions/environment. On the other hand, support from the environment such as the role of parents, teachers and the school environment also plays a very important role in building students' learning motivation (Fan & Williams, 2018; Šimunović & Babarović, 2020). A good environment such as support from parents, friends and teachers will motivate students to learn to solve problems. Positive interactions with this environment can create a pleasant learning atmosphere and support students' academic and emotional development (Arianti, 2019). The importance of motivation to learn has encouraged various studies that focus on effective ways of doing so (Febrita & Ulfah, 2019). Learning motivation factors are to find strategies that can be applied in various educational contexts to help students achieve their maximum potential (Suharni, 2021). Applications to online teaching materials, such as the inclusion of more engaging content, interactive components, and individualized feedback, have important beneficial impacts on learning motivation (Yang et al., 2025). By implementing online learning media that meet students' motivational needs and encourage their active participation in the learning process, one of the online learning media is PhET Virtual Lab. By understanding the factors that influence learning motivation and the research results from several researchers, students can understand the energy transformation material more easily through the PBL model using the PhET Virtual Lab which can provide support for increasing learning motivation in students.

In the context of energy transformation material, PBL allows students to explore concepts more critically and in depth, facilitating understanding through exploration and discussion (Kassymova et al., 2020; Tan, 2021). By presenting real problems related to energy transformation, which can ultimately increase their interest and motivation to learn. As technology develops, use Virtual Laboratory such as PhET (Physics Education Technology) as a learning medium can support and enrich the PBL model in teaching (Bao & Koenig, 2019; Ellermeijer & Tran, 2019). PhET is an interactive simulation that allows students to learn through virtual experiments, observing various scientific phenomena safely and in detail. The PhET Virtual Lab simulation is a device or tool that uses digital technology. PhET Virtual Lab is an interactive simulation that uses the internet to combine it using programming languages, namely flash and Java programs (Mahzum et al., 2024). By utilizing PhET, teachers can directly observe the energy transformation process through interactive and visual simulations. how PhET Virtual Lab works, namely learning media used is transformed into a series of experimental settings into interactive software based multimedia that is capable of simulating laboratory activities to represent a virtual lab, making it possible to handle activities directly that cannot be done directly in the lab (Marlina, 2022). In the context of education in Indonesia, the importance of developing learning methods that are interesting and capable of fostering student learning motivation is still a big challenge. The use of problem-based learning models supported by technology such as PhET is expected to be able to answer this need.

This work has a number of new aspects that make an important contribution to the development of science learning at the elementary school level, especially regarding energy transformation material. The first novelty lies in the use of the PBL model combined with Virtual Lab PhET technology, which is still rarely applied in learning contexts at the elementary level. While the PBL approach is more commonly applied in secondary or higher education, this research offers an innovative approach by implementing technology-based PBL at the elementary school level, especially for science learning (Fakhri et al., 2022). Apart from that, this research also introduces the use of the PhET Virtual Lab, which is often considered abstract and difficult to understand by students at the elementary level (Sari, 2020). Even though Virtual Lab PhET has been widely used in higher education as a science learning aid, its application in elementary schools is still minimal (Alfiah & Dwikoranto, 2022), especially in increasing student learning motivation (Arifudin, 2021). Therefore, this research not only explores Virtual Lab PhET as a visual aid, but also as an effective medium for triggering students' motivation, enthusiasm and curiosity towards basic scientific concepts. The expected benefits of this research can help teachers use effective learning media and can increase student motivation in learning.

Method

This research is quantitative approach quasi-experimental (Maciejewski, 2020). The approach quasi-experimental was chosen to identify differences in student learning motivation with the two models. Design this work with Nonequivalent Control Group Design (Krishnan, 2024). The population of this work is all students at SDN Triharjo. Sample with purposive sampling. Two classes were taken as samples, with one class as an experimental group that applied the PBL Model assisted by Virtual Lab PhET and a conventional class.

The research instrument is a tool used as a benchmark in measuring the variables determined in the study to obtain quantitative information (Fauziyah et al., 2023). The main instrument of this study is a

questionnaire. This questionnaire consists of a number of statements arranged based on learning motivation indicators, such as interest in learning, perseverance in facing tasks, enthusiasm for learning, curiosity, support from parents, teachers, the environment, and the application of learning media/materials. The questionnaire is made in the form of closed questions or objective. The assessment of the questionnaire so that it is easy to analyze using a Likert scale with 5 scales, namely strongly agree (5), agree (4), undecided (3), disagree (2), strongly disagree (1). The number of questionnaire items consists of 10 questions. In addition, additional instruments in the form of observation sheets are also used to record student involvement during teaching and learning activities, both in experiments and controls. Additional observation sheets used such as student name lists and assessment rubrics. Observations were carried out on students at SDN Triharjo which were carried out by researchers and accompanied by class teachers.

This work begins with preparation. In the preparation stage, a learning plan is prepared that applies the PBL Model assisted by PhET Virtual Lab for the experimental group. The learning plan that will be carried out is to provide energy transformation material using the PBL learning model to each experimental class and control class. Energy transformation learning materials and relevant learning tools are also prepared for the control group with conventional learning. The steps for using PhEt Virtual Lab in the learning process are that students are asked to open the PhET site, students are asked to press the Play button to simulate the energy transformation material, then students are guided to conduct experiments with the instructions given, when conducting the experiment the teacher asks students to observe the results of the experiment, then students are asked to provide conclusions regarding the results of the experimental observations carried out. Before implementation, a questionnaire instrument trial was carried out to ensure the validity and reliability of the data to be analyzed.

Next, in the implementation stage, students in the experimental class use this model. The learning process begins by providing problems related to energy transformation that students must solve, then continued with exploration using PhET Virtual Lab. The teacher conducts learning to the experimental class with the PBL learning model collaborated with the application of PhET Virtual Lab in seeing students' learning motivation. While in the control class using conventional KBM according to the applicable curriculum, without the help of PhET Virtual Lab. The teacher conducts learning to the control class with the PBL learning model without collaborating with the application of PhET Virtual Lab in seeing students' learning motivation. Students and teachers conduct simulations or practices on energy transformation material in the experimental class and control class. During the teaching and learning process, observations are made on the involvement and responses in each group to obtain supporting data related to students' learning motivation.

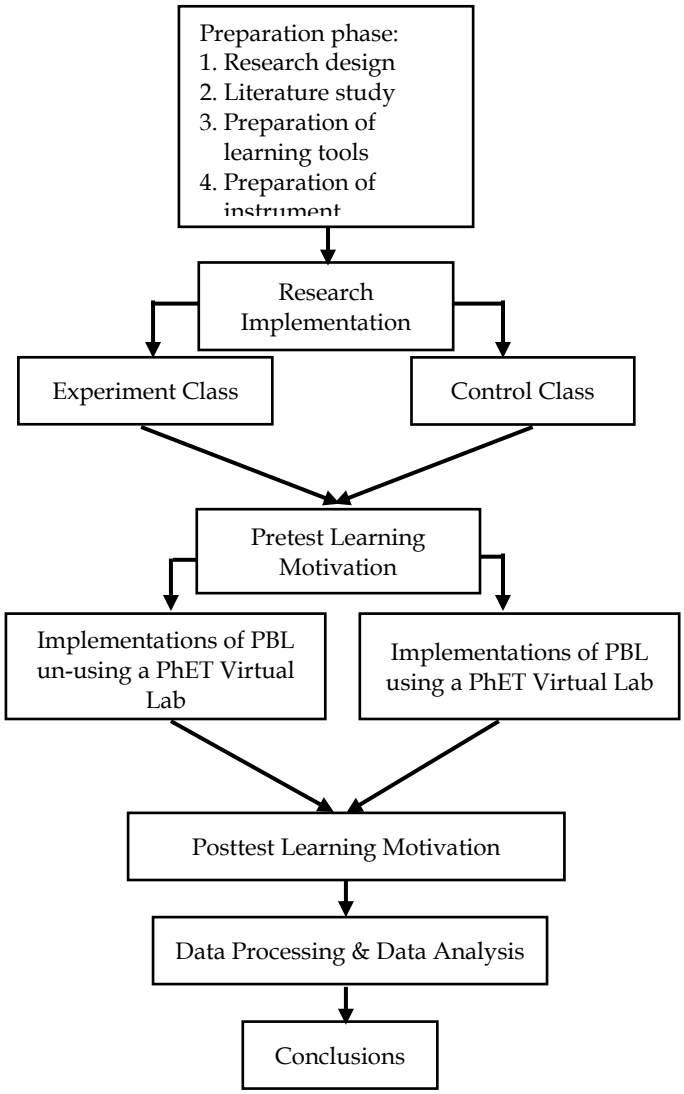

Figure 1. Research flow

The data collection stage was carried out after the learning process was completed. The learning motivation questionnaire was distributed to students in both groups to measure their learning motivation. In addition, observation data was also collected as supporting data. The statistical method was carried out after going through the questionnaire testing stage. The first stage in this analysis is descriptive analysis. Important information related to the distribution, central tendency, and variation of existing data is obtained through this descriptive analysis. Descriptive statistical testing by finding the minimum, maximum,

mean, and standard deviation values. After that, the next step is to conduct a normality test which is an important prerequisite for conducting parametric statistical tests. Normality testing uses Shapiro-Wilk with the condition sig. > 0.05. If the data meets the assumption of a normal distribution or sig. > 0.05, a paired sample t-test is carried out. The paired sample t-test is used with a sig. <0.05, if the sig. paired sample t-test value < 0.05 then H0 is rejected and Ha is accepted, meaning that the PBL Model assisted by the Virtual Lab PhET has an effect on learning motivation. Then the analysis process is carried out using a homogeneity test. This homogeneity test is very important to ensure that the comparison between the two groups is not influenced by significant differences in variance. Homogeneity testing uses a homogeneity test of variance with a sig. level of 0.05. If the homogeneity test value based on mean > 0.05 then the variance of the research data is declared homogeneous. If the results of the homogeneity test indicate that the variance between groups is not much different, then an independent sample t-test is carried out. The paired sample t-test is used with a sig. value < 0.05, if the sig. value of the independent sample test < 0.05 then the application of the PBL Model assisted by Virtual Lab PhET and the PBL Model not assisted by Virtual Lab PhET there is a difference in the resulting learning motivation.

Result and Discussion

Findings from research at SD Negri Triharjo: Energy Transformation Material on Learning Motivation of SD Negri Triharjo Students "using a Likert scale in data collection. Researchers used SPSS 16 software to analyze the data and provide a questionnaire (Sirager, 2018). Each statement was evaluated for the validity of the data using five alternative options with the following categories.

Table 1. Likert scale

Statement items	Score weight				
	A	B	C	D	E
Positive	5	4	3	2	1

Description: Always, Often, Sometimes, Never

The table presented above is the result of data collection carried out using the research methods described previously. At this stage, the results of the questionnaire that has been distributed will be revealed. The questionnaire was given to 44 respondents with the aim of comparing. The data collection process was carried out very carefully and systematically, starting from selecting a representative sample, distributing questionnaires to appropriate respondents, to analyzing the answers obtained from each respondent.

The data collected through this questionnaire will then be analyzed using various appropriate statistical methods, including descriptive analysis to describe the general characteristics of the data, normality test to compare two paired groups, homogeneity test to see the similarity of variance between groups. All of these tests aim to understand more deeply how those who apply the PBL model assisted by the PHET virtual lab and those who do not apply it.

The results of this analysis will be understood carefully and interpreted to provide a deeper understanding of the impact of implementing this learning model on student motivation. Comprehensive data presentation and incisive analysis will provide a strong foundation for accurately conveying the findings of this research, as well as providing clear insights, as explained in the following section.

Table 2. Descriptive statistics

	N	Min	Max	Mean	Std. Deviation
Pre-Teat Experiment	22	24	45	35.32	5.84
Post-Experiment	22	36	49	44.09	4.20
Pre-Test Control	22	24	48	35.18	5.97
Postal Control	22	25	46	37.73	6.56
Valid N (listwise)	22				

Based on the results of the descriptive statistical analysis shown in the table, we can see various important information related to the existing data, such as the maximum value, average value and minimum value which describes the variation and distribution of the data. Apart from that, the table also shows the total amount of data explaining the size of the sample analyzed. After obtaining a general idea from descriptive statistical analysis, the next step is to carry out a normality test (Sirager, 2018). This test aims to evaluate whether the existing data distribution follows a normal distribution pattern or not. This process is very crucial because the results of the normality test will influence the choice of subsequent statistical analysis methods. If the data is proven to be normal, then parametric analysis can be applied, but if the data does not meet the assumption of normality, then non-parametric analysis may be more appropriate.

This normality verification process is carried out using two common statistical tests. According to the procedures applied in quantitative analysis, data is considered to be normally distributed if the p-value of the two tests is greater than 0.05. This figure does not experience significant deviations from the normal distribution, which is one of the requirements for carrying out further analysis using parametric statistical techniques. With data that meets the normal distribution

criteria, the next step is to use parametric statistical methods to analyze the data further.

Table 3. Tests of normality

Class		Shapiro-Wilk		
		Statistic	df	Say.
Student Motivation Results	Pre-Test Experiment PBL	.93	22	.14
	Post-Test Experiment PBL	.90	22	.03
	Pre-Test Control	.96	22	.51
	Post Test Control	.91	22	.05

Table 4. Test of homogeneity of variance

		Levene Statistic	df1	df2	Sag.
Student Motivation	Based on Mean	3.54	1	42	.07
	Based on Median	2.59	1	42	.12
	Based on Median and with adjusted df	2.59	1	32.25	.12
	Based on trimmed mean	3.22	1	42	.08

The homogeneity test carried out aims to identify differences in the variance of data from 2 or more groups, whether the groups are homogeneous (uniform) or heterogeneous (varied). The requirement for an independent sample t-test is the presence of homogeneous data, because the independent t-test requires the assumption that the variances in the two groups being compared are the same. As shown in the table, the Sig Based on Mean value is 0.067. This value is greater than the critical limit of 0.05, indicating that there is similarity between the variances of the two, namely between the experimental class and the control class. The distribution of data in the two groups has a relatively similar level of spread, which indicates that they can be considered homogeneous. After the research data is declared normal and homogeneous, the next step is the analysis using the independent sample t-test have been met (Sirager, 2018).

Table 5. Independent sample test

		t	df	Sig. (2-tailed)
Student Motivation	Equal variances assumed	3.83	42	.00
	Equal variances not assumed	3.83	35.71	.00

Based on the analysis conducted to see students' learning motivation. The df value shows that the number of variants of independent samples is 42. The t-test value is 3.83 and the independent sample test is seen at the sig value. (2-tailed) equal variance assumed 0.00 < 0.05. This shows that there is a significant difference between students' learning motivation using the PBL learning model in the form of PhET Virtual Lab and PBL learning without the help of PhET Virtual Lab for Energy Transformation material on Triharjo state. The independent sample t test in experimental research must be carried out as a guide to find out from a comparison of two or several groups which received treatment and which did not. So, with the independent sample t test, we can find out the answer to the problem formulation in comparing two classes that apply and do not apply the PhET Virtual Lab Assisted PBL Model for Energy Transformation Material on Triharjo State.

The method is the t test for paired sample t-test and the t test for independent sample t-test (Sirager, 2018). Both require the assumption of normality in the data so that the results obtained can be valid and can be interpreted correctly. The paired samples t test is used when the researcher wants to compare two conditions or two variables that come from the same group or are related to each other. The independent samples t test is used when two groups are different and unrelated to compare, such as comparing two groups that received different treatments.

Table 6. Paired sample test

		t	df	Sig. (2-tailed)
Pair 1	Pre-Test Experiment - Post-Test Experiment	-15.94	21	.00
Pair 2	Pre-Test Control - Post-Test Control	-2.94	21	.00

The analysis results for Paired sample t-test show a significance value (2-tailed) of 0.000, smaller than 0.05. Indicates the difference between the average student learning motivation pre-test and post-test when implementing the PBL model with the help of the PhET virtual lab in the experimental class. In more detail, this difference reflects that the application of problem-based learning methods equipped with PhET virtual lab technology is closely related to increasing student learning motivation. This means that students show an increase in their enthusiasm and involvement in the learning process after using this approach, compared to conditions before the model was applied. The use of PhET lab-assisted PBL is effective in stimulating student motivation (Sirager, 2018).

Table 7. Group Statistics

	Class	N	Mean	Std. Deviation	Std. Error Mean
Student Motivation	Post-Test PBL Experiment class	22	44.09	4.20	.90
	Post-Test Control class	22	37.73	6.56	1.40

Elementary School Students' Learning Motivation. In Table 7 you can see the differences in student motivation in which the PhET Virtual Lab Assisted PBL Model is applied and which is not applied (experimental and control).

Group statistical analysis for the experiment in seeing students' learning motivation with a total of 22 students, and a control class of 22 students. The average post-test score after the PBL learning model was carried out in the experimental class assisted by PhET Virtual Lab was 44.09 with a standard deviation of 4.20, while in the control class the PBL learning model without the assistance of PhET Virtual Lab the average score was 37.73 with a standard deviation of 6.56. The difference in the average scores of students in the experimental class and the control class shows that there is a difference in the scores of students' learning motivation achieved. The analysis shows that the value of students' learning motivation in the experimental class is greater than the value of students' learning motivation in the control class. This shows that the PBL learning model assisted by PhET Virtual Lab is more effective to be applied to students in studying the material of transformation energy. The results of the group statistical analysis are in accordance with the results of the independent sample analysis which shows that there is a significant difference.

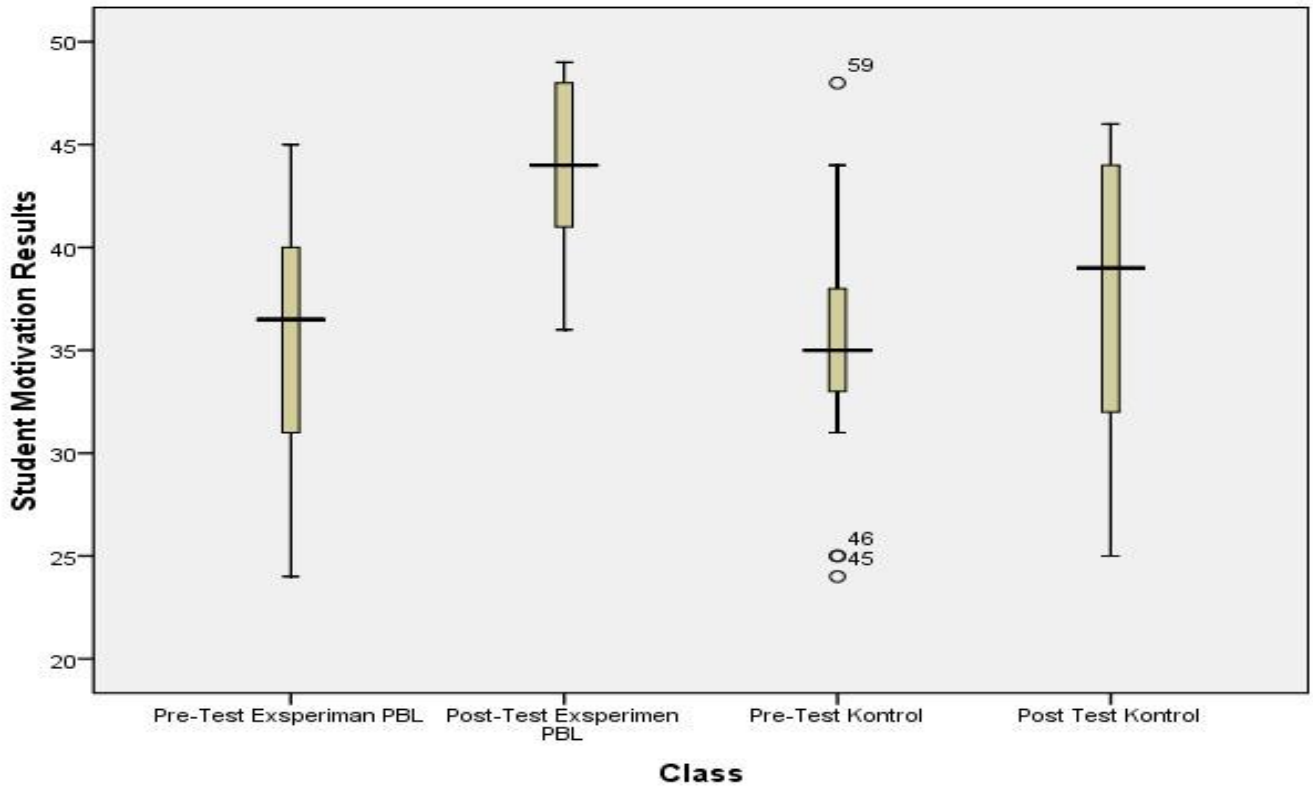

Figure 2. Student motivation level

The analysis results for Pair 1 show a significance value (2-tailed) of 0.000, smaller than 0.05. Indicates the difference between the average student learning motivation pre-test and post-test when implementing the PBL model with the help of the PhET virtual lab in the experimental class. In more detail, this difference reflects that the application of problem-based learning methods equipped with PhET virtual lab technology is closely related to increasing student learning motivation. This means that students show an increase in their enthusiasm and involvement in the learning process after using this approach, compared to conditions before the model was applied.

The results of this study have a significant influence between the experimental class and the control class. This is related to previous researchers who have explained that the problem-based learning model has an influence on students' learning motivation when learning (Hamdani et al., 2022). Research conducted by Mardani et al. (2021) results that there is an influence on the motivation and learning outcomes of students who follow the Problem Based Learning learning model with the conventional model in social studies learning class

VIII SMP Negeri 3 Sukasada. Research conducted by Azizi & Irwansah (2020) that It can be concluded that the Problem Based Learning model can improve motivation and learning outcomes in the X class of MIA MA Darul Aminin NW Aikmua. The results of M. Miftach Fakhri's research show that the learning outcomes and motivation of experimental class students have significant differences with control class students through Blended Problem Based Learning (Fakhri et al., 2022).

Problem-based learning is an educational model that provides students with experiences to explore a concept and develop critical thinking skills. This learning approach focuses on real-world problems and working together to solve them (Dwiyanti & Setyasto, 2025). The Problem-Based Learning (PBL) model was chosen because it has multiple solutions in solving the problem and improves the ability to think critically which means that students are motivated to learn because the indicators of learning motivation are consistent with the steps of problem-based learning (Regina & Wulandari, 2025). PBL can build close relationships between the concepts and facts being studied because students are actively involved in collaborating to search for information (Firanti et al., 2025). The project-based learning model allows students to have quality learning activities in visual, written, kinesthetic, oral, auditory and mental activities (Buntu et al., 2025). The problem-based learning model can influence students' learning motivation, because the PBL learning model invites students to be active in learning by providing problems to be solved (Nur & Ikhsan, 2024).

Learning motivation is a psychological stimulus in a person to gain knowledge or learn (Bobi et al., 2023). Psychological stimulation in learning motivation will create students' desire and interest in learning which is the main key to the success of the learning process received (Dini et al., 2023). Motivation plays a role in physics learning, because student motivation that occurs will determine the success of learning outcomes. Student enthusiasm when learning the subject results in better learning habits, improved assessment performance, and a deeper understanding of the material (Rizki et al., 2025).

Group statistical analysis for the experiment in seeing students' learning motivation with a total of 22 students, and a control class of 22 students. The average post-test score after the PBL learning model was carried out in the experimental class assisted by PhET Virtual Lab was 44.09 with a standard deviation of 4.20, while in the control class the PBL learning model without the assistance of PhET Virtual Lab the average score was 37.73 with a standard deviation of 6.56. The difference in the average scores of students in the experimental class and the control class shows that there is a difference in the scores of students' learning motivation achieved. The analysis shows that the value of students' learning motivation in the experimental class is greater than the value of students' learning motivation in the control class. The independent sample test is seen at the sig value. (2-tailed) equal variance assumed 0.00 < 0.05. This shows that there is a significant difference between students' learning motivation using the PBL learning model in the form of PhET Virtual Lab and PBL learning without the help of PhET Virtual Lab for Energy Transformation material on Triharjo state. This research is in accordance with (A) which proves that there is a significant difference between classes that use the application of learning media in the PBL learning model regarding the learning motivation it generates and classes that do not use learning media in the PBL learning model regarding learning motivation (Ananda et al. 2023). This shows that the PBL learning model assisted by PhET Virtual Lab is more effective to be applied to students in studying the material of transformation energy. The results of the group statistical analysis are in accordance with the results of the independent sample analysis which shows that there is a significant difference.

Conclusion

Based on the results of the research and the actions and discussions in the previous material, a detailed conclusion can be drawn, namely that there is a difference in the average learning motivation of students between those who applied the PBL Learning Model Assisted by PhET Virtual Lab on Energy Transformation Material and those who did not apply it. Statistical analysis of the group for the experimental class in seeing student learning motivation with a total of 22 students, and a control class of 22 people. The average post-test score after the PBL learning model was carried out in the experimental class assisted by PhET Virtual Lab was 44.09 with a standard deviation of 4.20, while in the control class the PBL learning model without the assistance of PhET Virtual Lab the average score was 37.73 with a standard deviation of 6.56. The difference in the average scores of students in the experimental class and the control class shows that there is a difference in the value of student learning motivation achieved. The results of the Paired sample t-test analysis showed a significance value (2-tailed) of 0.000, less than 0.05. So, the PBL Model assisted by PhET Virtual Lab has a significant influence on students' learning motivation which is higher than the PBL Model without the assistance of PhET Virtual Lab for students at Triharjo Elementary School. This proves that the PBL learning

model assisted by PhET Virtual Lab in understanding Energy Transformation Material can increase students' learning motivation.

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Author Contributions
T. A. S contributed to conceptualization, overall design of activities, PhET Virtual Lab teaching strategies, data analysis, ensuring statistical accuracy, and creating visualizations to present findings, and literature review. A. F. N helped develop the research methodology and supervised data collection, A. A. M assisted in drafting the manuscript, B. H. C. K contributed to the revision and editing of the final version of the article. All authors have read and approved the final manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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