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UNIVERSITY STUDENT'S RESPONSES' TOWARDS THE USE OF PHET-BASED VIRTUAL LABORATORY ON THE BASIC OF SCIENCE CONCEPTS COURSE

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Abstract: The rapid development of educational technology has brought significant changes to science learning, primarily by integrating virtual laboratories. These tools provide interactive and student-centered experiences that are more accessible than conventional labs. This study explores the importance of PhET-based virtual labs in enhancing students' understanding of energy and work concepts in a Basic Science Concepts course, emphasizing their relevance in modern, inquiry-based science education. This research analyzes university students' perceptions of the usability and quality of PhET simulations used in the course. Using a quantitative survey method, data were collected from 161 randomly selected university students through a Likert-scale questionnaire. The results show an overall satisfaction rate of 71.68%, indicating a positive response categorized as "good." Students particularly appreciated the user-friendly interface and dynamic visualizations that encouraged independent exploration and more profound comprehension of abstract concepts. The study concludes that PhET-based virtual labs are practical supplementary tools in science education. Despite limitations such as reliance on self-reported data and short-term evaluation, the findings highlight the potential of virtual labs to enhance conceptual learning. Future research should investigate long-term learning outcomes and compare virtual, traditional, and blended learning environments to optimize instructional strategies.

Keywords: Energy, PhET, Virtual Laboratory, University Students' Response

INTRODUCTION

The rapid advancement of technology in education has significantly influenced the development of innovative learning approaches. Among these innovations, virtual laboratories (virtual labs) have emerged as a transformative tool in science education. By offering interactive and flexible learning environments, virtual labs allow students to conduct scientific simulations and experiments without being bound by the physical constraints of traditional laboratory settings (Diab et al., 2024; Firdaus et al., 2023; Idiawati et al., 2024). This flexibility is especially beneficial in educational contexts where access to complete laboratory

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infrastructure is limited, thus supporting equitable and inclusive science learning experiences.

One of the most recognized platforms in virtual labs is PhET Interactive Simulations, developed by the University of Colorado Boulder. PhET provides free, research-based interactive simulations in physics, chemistry, biology, mathematics, and other sciences. Designed with inquiry-based learning, PhET simulations encourage students to explore scientific concepts through guided discovery, fostering more profound understanding and learner autonomy. In line with constructivist learning theory, which emphasizes the importance of active, hands-on experiences in building knowledge, PhET simulations are structured to help students construct meaning through visualization, manipulation of variables, and real-time feedback (Acquah et al., 2024).

The concepts of energy and work are foundational to the understanding of science. However, they are often considered abstract and difficult for students to grasp, especially without practical activities that demonstrate these concepts in action. Traditional classroom settings may struggle to provide adequate opportunities for experimentation due to resource limitations, safety concerns, or time constraints. This presents a significant challenge, as mastering these fundamental concepts is essential for students' success in more advanced scientific topics. Virtual labs, particularly those based on PhET simulations, offer a practical alternative by simulating real-world phenomena and allowing learners to engage in experimental tasks that are otherwise difficult to replicate in a conventional classroom (Liani et al., 2022).

Several recent studies have demonstrated the effectiveness of PhET simulations in enhancing learning outcomes in science education. For example, (Rusnayati & Ariantara, 2024) found that using PhET simulations in solid-state physics led to a moderate increase in students' conceptual understanding, as indicated by an n-gain of 0.51. Besides, (Amin & Yuneti, 2024) reported significant learning gains in energy conversion topics, with students achieving an average post-test score of 85. Similarly, a study conducted by (Sinaga et al., 2025) showed improved outcomes in learning the Compton effect through PhET-assisted instruction. Moreover, (Alsalhi et al., 2024) emphasized that using virtual labs can be especially impactful in higher education settings, where abstract scientific concepts require more sophisticated instructional tools.

Despite the growing body of literature supporting the academic benefits of PhET, there remains a gap in understanding how students perceive their experience with these virtual labs—particularly about usability and content quality, which are critical factors for student engagement and learning effectiveness. Most previous studies have focused on academic performance indicators, with fewer examining

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learners' subjective responses, which are equally important in evaluating educational technologies' long-term viability and impact.

Therefore, this study seeks to examine university students' responses to the use of PhET-based virtual labs in the context of learning energy and work. Specifically, it focuses on student attitudes toward usability—such as ease of navigation and accessibility—and the quality of content presented in the simulations, including clarity, relevance, and support for independent learning. Rather than directly measuring conceptual understanding, the study emphasizes how students experience and engage with the virtual lab environment, which is critical in evaluating the effectiveness and sustainability of technology integration in science education. The findings are expected to provide practical insights for educators, instructional designers, and policymakers in optimizing the use of virtual simulations to support engaging and effective science learning.

METHOD

The research method used was a survey with data collection techniques, distributing university student response questionnaires through Google Forms. The population in this study amounted to 188 university students who programmed introductory science concepts courses at one of the LPTKs in Makassar. The research sample amounted to 161 students who were selected using *random sampling* techniques, with *a margin of error* of 3%. The determination of the number of samples uses the Slovin formula as follows.

$$n = \frac{N}{1+N\times e^2} \tag{1}$$

with:

- N = total population
- *e = margin of error*

The research instrument is in the form of a questionnaire on a Likert scale of 1-5, which consists of aspects of ease of use *of the virtual lab* and the content of energy materials. Furthermore, the scoring of the questionnaire data includes a scale of "Strongly Agree" has a score of 5, "Agree" has a score of 4, "Enough" has a score of 3, "Disagree" has a score of 2, and "Disagree" has a score of 1. The indicators of each aspect are presented in Table 1.

Table 1. Aspects and Indicators of Student Response Questionnaire

No.	Aspects	Indicators
1.	Ease of use	Availability of Guidelines
		Navigation

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		Accessibility
		Ease of Exploration
		Stability and Performance
2.	Energy material	Potential energy
		Kinetic energy
		Mechanical energy
		Visual Representation and Interactive Simulation
		Linkage to Real Phenomena

The student response data was then analyzed using quantitative descriptive analysis techniques using the following formula.

$$P = \frac{f}{n} 100\% \tag{2}$$

Formula description:
P = Percentage of Assessment Score
f = Score obtained
n = Maximum expected score

Furthermore, an interpretation of the student response data was carried out using the criteria in Table 2.

Table 2. Interpretation category for university student response percentage

Percentage (%)	**Category**
0 – 20	Very Weak
21 – 40	Weak
41 – 60	Fair
61 – 80	Good
81 – 100	Excellent

(Zahidah et al., 2023)

Furthermore, the normality test was also conducted using the Kolmogorov-Smirnov test in order to determine if a dataset follows a normal distribution. The data were also analyzed using a one-sample t-test. One-sample t-test was used in this study to examine whether the average student's response to using the PhET Virtual Lab differs significantly from a predetermined reference value of 70. This

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reference value represents the midpoint of the "good" category on the student response scale. By employing this test, we aim to determine whether students' experiences with the PhET Virtual Lab tend more positive or more negative responses compared to this standard value. The one-sample t-test enables statistical decision-making regarding the null hypothesis (H_0), which states that the average student response equals 70, and the alternative hypothesis (H_a), which asserts that the average student response is not equal to 70. This analysis provides a statistical basis for assessing the extent to which the use of the PhET-based virtual laboratory is accepted and appreciated by students.

RESULTS AND DISCUSSION

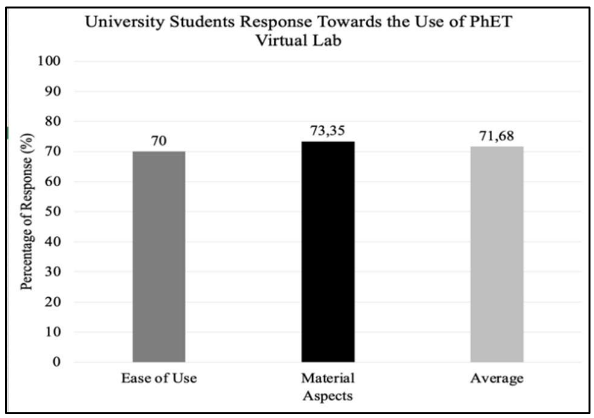

Figure 1. Graph of Average Student Response

The results presented in Figure 1 indicate that the average student response to using PhET-based virtual laboratories in the Basic Science Concepts course was 71.68%, which is categorized as "good". This suggests that students generally held favorable perceptions regarding the usability of virtual simulations in facilitating their understanding of the concepts of energy and work. This is because PhET consists of interactive tools that allow students to conduct a virtual experiment properly.

These findings are consistent with the study conducted by (Faizah et al., 2023), which demonstrated that system quality significantly influences perceived usefulness, while perceived ease of use directly impacts students' behavioral intention to utilize educational technology. The user-friendly interface and interactive visualizations provided by the PhET simulations likely contributed to this positive reception, indicating the importance of design features in promoting user acceptance. Moreover, the students' response data were also tested using Kolmogorov-Smirnov to examine the data distribution. The output of the Kolmogorov-Smirnov test is shown in Figure 2.

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Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Students' Response	.069	161	.062	.977	161	.009

a. Lilliefors Significance Correction

Figure 2. SPSS output of Kolmogorov-Smirnov test of normality

Based on the output, it is known that the significance value is 0.062 > 0.05 which indicates that the data was normally distributed. Subsequently, a one-sample t-test was conducted, and the output is shown in Figure 3.

One-Sample Test

	Test Value = 70						
			Significance		Mean Difference	95% Confidence Interval of the Difference	
	t	df	One-Sided p	Two-Sided p		Lower	Upper
Students' Response	4.610	160	<.001	<.001	4.3292	2.475	6.184

Figure 3. SPSS output of One-sample t-test

The study reveals that the mean student's response to using PhET Virtual Lab is 71.68. The result shows that it is significantly different from the benchmark value of 70 ($p < 0.001$). This statistically significant difference indicates that students' experiences with the virtual lab are not only positive but also exceed the expected standard, suggesting a favorable perception toward the integration of PhET simulations in science learning.

The score of 71.68 falls within the "good" category, highlighting that students generally respond well to the implementation of virtual labs in their learning process. This finding aligns with recent studies that demonstrate the potential of interactive simulations to enhance conceptual understanding and increase engagement in science education. For instance, (Alnaser & Forawi, 2024; Asare et al., 2023) found that using virtual labs in physics instruction significantly improved students' attitudes and learning outcomes compared to traditional methods.

Moreover, the use of PhET simulations supports student-centered learning, offering opportunities for experimentation, visualization, and exploration of abstract concepts in a controlled and engaging environment (Dy et al., 2024). These features are particularly beneficial in courses where access to physical laboratories is limited or where students require more interactive and inquiry-based learning experiences. The statistically significant result ($p < 0.001$) also underscores the effectiveness of the intervention, supporting the notion that the use of digital tools

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like PhET can be more than just a supplement to traditional learning — it can be a powerful pedagogical strategy in its own right. The positive response of students in this study suggests that such tools can contribute to higher levels of motivation, conceptual clarity, and satisfaction during the learning process.

In addition to the significance of the findings, the accuracy and reliability of the data are supported by the sampling size. The study involved 161 students**,** and with this sample size, the margin of error is approximately ±3% at a 95% confidence level. This indicates a high level of precision in the estimation of the population mean response. In other words, we can be 95% confident that the true average student response lies within ±3% of the observed mean of 71.68 (Gilliland & Melfi, 2010). This narrow confidence range further strengthens the credibility of the conclusion that student responses are significantly and meaningfully above the benchmark of 70.

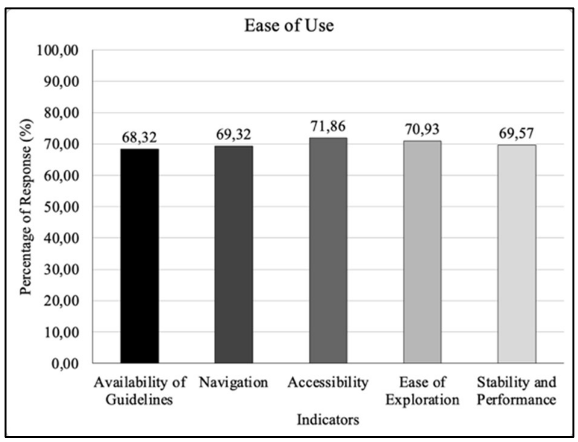

Figure 4. Graph of Student response's on the aspect of ease of use PhET

Furthermore, an in-depth analysis was carried out on each aspect of the student response. First, student responses on the aspect of ease of use showed that the accessibility indicator achieved the highest percentage of 71.86%. This indicates that the majority of students feel that PhET-based virtual laboratory are easily accessible, both in terms of the devices used and the internet connection required (Dy et al., 2024; Mohamad et al., 2023; Rizal et al., 2024). In addition, other indicators such as the navigation of the interface and the readability of the instructions also received positive responses, indicating that the PhET-based virtual lab interface is quite intuitive and can be used without complicated additional guidance (Riastuti et al., 2024).

In line with these findings, the study (Assaf, 2025) showed that students appreciated the user-friendly interface as well as the manipulative capabilities of the PhET simulation. These features allow them to experiment and explore science concepts in a more fun way. This positive engagement significantly improves their overall learning experience, making abstract concepts more real and accessible

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(Purba et al., 2025; Siswoyo & Muliyati, 2021). Thus, the use of PhET-based Virtual Labs contributes to a deeper understanding and increased student confidence in understanding the material (Sari & Zamrah, 2024).

Furthermore, another research (Kumar, 2024) proves that PhET obtained excellent assessments on accessibility and flexibility aspects, where PhET accommodates various learning styles by combining text, video, multimedia, and animation. This variety allows users to engage with the material in a way that best suits their learning style. In addition, the interactive features in PhET make it easier to use compared to conventional learning methods. Meanwhile, in terms of compatibility, PhET is very easy to use on various devices, thus increasing user engagement (Salam et al., 2024).

Based on the description above, it can be stated that PhET-based Virtual Labs have a high level of accessibility and an easy-to-use interface, allowing students to use them independently. This convenience not only increases efficiency in learning but also strengthens students' conceptual understanding.

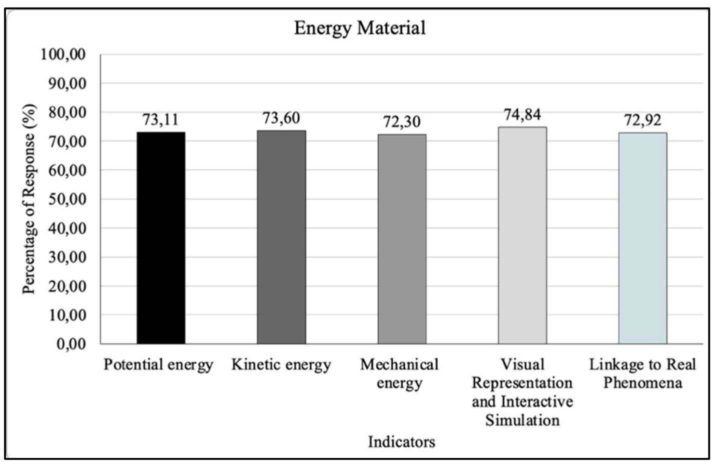

Figure 5. Student response to the aspect of energy material content

The next aspect is the content of energy material, which includes potential energy, kinetic energy, mechanical energy, visual and simulated representations, and linkages with real phenomena. The data shows that the average percentage of student responses is in the range of 72% - 75% with the good category. This shows that PhET simulation contains material that is relevant to the purpose of the lecture.

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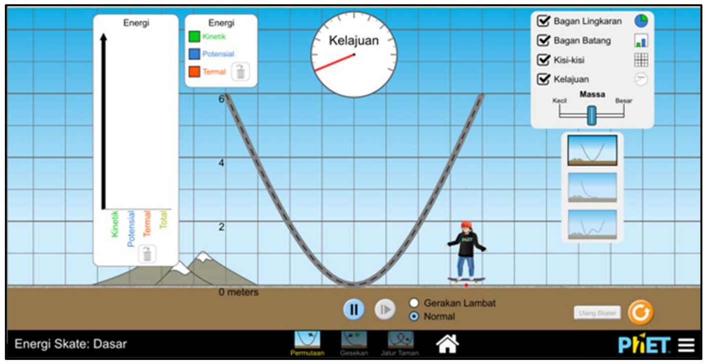

Figure 6. Virtual view of the Lab "Basic Energy Skatepark"

This simulation allows users to visualize and manipulate kinetic and potential energy as they navigate a virtual skate park, making abstract physics principles more tangible. The effectiveness of this tool aligns with various studies, highlighting its impact on student engagement and comprehension. The simulation facilitates the exploration of kinetic and potential energy, allowing students to observe energy transformations in real-time (Sudirman et al., 2024). Moreover, Students demonstrated significant improvement in their understanding, with post-test scores increasing from an average of 62.67 to 86.67 after using the simulation (Sudirman et al., 2024). Besides, Interactive features enable students to analyze relationships between forces and energy changes, enhancing their ability to interpret graphs and data as seen in figure 5 (Siswoyo & Muliyati, 2021).

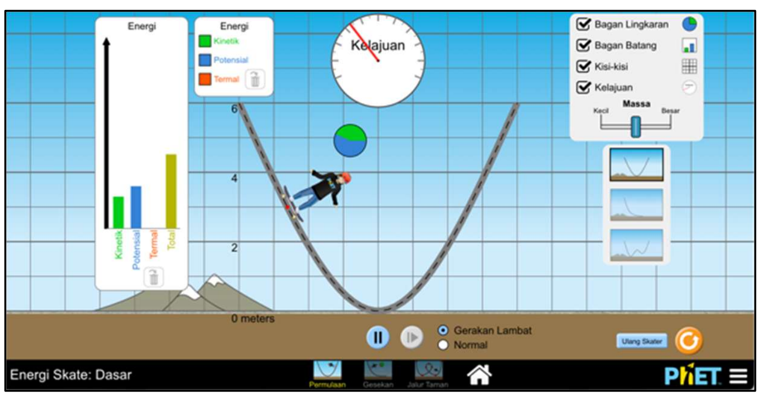

Figure 7. Interactive features of PhET

The results of research in recent years also support these findings. The application of scientifically-based PhET simulations to energy conversion materials increased the learning interest of physics education students, with the percentage of learning interest reaching 73.17% (Amin & Firdaus, 2023). This shows that the use of simulation not only increases the understanding of concepts, but also the motivation of students to learn. Other research also proves that the use of PhET simulations in physics learning on the law of conservation of mechanical energy material is quite effective, with an increase in the percentage of learning

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completeness from 68% in the pre-test to 100% in the post-test (Rasyidi et al., 2024).

These findings suggest that the use of PhET simulations in learning energy materials can improve understanding of related concepts and skills. With dynamic and interactive visual representations, students more easily associate energy concepts with their applications in daily life. The clarity of the simulation in showing the change of potential energy into kinetic energy and vice versa also provides a more real learning experience compared to conventional methods (Amin & Yuneti, 2024; Husein et al., 2024; Nio et al., 2024). However, while the average response is categorized as “good”, it has not yet reached the "very good" category (score > 80), indicating that there may still be room for improvement in how the PhET Virtual Lab is implemented. Factors such as the design of accompanying learning activities, student digital literacy, and instructor facilitation influence how effectively students engage with and benefit from virtual simulations (Asare et al., 2023).

CONCLUSION

University students’ perceptions to the PhET-based Virtual Lab in learning energy and work concepts fall within the “good” category. This proves that students perceive the use of interactive simulations as a valuable support for learning, particularly in visualizing and exploring the relationships between different forms of energy. Given the high level of accuracy and consistent positive perception, it is recommended that PhET simulations be further developed and integrated into science instruction. This can be achieved by embedding simulations into guided inquiry-based modules, offering professional development for educators to enhance facilitation skills, and combining virtual labs with real-life or hands-on activities. Such efforts can help maximize the potential of PhET tools to improve students’ conceptual understanding and support more meaningful, engaging, and applicable science learning experiences.

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