



## Application of PhET Simulation-Assisted Problem-Based Learning Model in Improving Students' Critical Thinking Skills on Rotational Dynamics Material

Fadia Mustikazahra\*, Hera Novia, Lina Aviyanti

Physics Education, Universitas Pendidikan Indonesia, Bandung, 40154, Indonesia

### ARTICLE INFO

#### Article history:

Received: 22 April 2025

Revised: 29 May 2025

Accepted: 11 June 2025

Published online: 05 July 2025

#### Keywords:

Problem-Based Learning Model;  
PhET Simulation;  
Students' Critical Thinking Skills;  
Rotational Dynamics Material

#### \* Corresponding author:

E-mail: [fadia@upi.edu](mailto:fadia@upi.edu)

#### Article Doi:

<https://doi.org/10.31258/jes.9.4.p.1742-1752>

This is an open access article under the [CC BY-  
SA](https://creativecommons.org/licenses/by-nc-sa/4.0/) license.



### ABSTRACT

This research investigates the effectiveness of the Problem-Based Learning (PBL) model assisted by PhET simulations in enhancing students' critical thinking skills on rotational dynamics. A quasi-experimental design was used in this research, involving two groups: an experimental group using PBL model with PhET simulations and a control group using PBL model without PhET simulations. The research participants were high school students, and data were collected through pre-test and post-test assessments measuring critical thinking skills. The findings indicate that students in the experimental group demonstrated significant improvement. Statistical analysis showed a higher mean score increase in the experimental group compared to the control group. These results suggest that the application of PBL with PhET simulations is an effective approach to fostering critical thinking in physics education, particularly in rotational dynamics.

## 1. Introduction

The 21st century, as the age of globalization, is an era where changes occur rapidly in both information and technology. In the field of education, 21st-century learning plays a crucial role in producing high-quality, superior, and competitive human resources (Mardhiyah et al., 2021). A person with strong critical thinking skills will evaluate given facts and reject inaccuracies or unfounded claims. Students who have these skills have a larger perspective and are more capable of making crucial decisions both at school and in their daily lives (Raj et al., 2022). However, in Indonesia, students' critical thinking skills remain low, as reflected in the PISA (Programme for International Student Assessment) rankings published by the OECD (Organisation for Economic Co-operation and Development).

Indonesia remains among the lowest-ranked countries, ranking 69 out of 81 countries in PISA 2022. Similarly, field observations indicate that students' critical thinking skills in science learning are remain categorized as low. Research by Basri et al. (2019) shows that critical thinking skills remain in the low category, with evaluation, analysis, and self-regulation being the weakest sub-skills. Consistent with these findings, the investigation conducted by Sarwanto et al. (2021) indicates that students' critical thinking abilities are at a notably low level, demonstrated by the observation that a mere 10% of students achieve scores exceeding the established minimum criteria. An identified element contributing to this observation is the employment of direct instruction paradigms by educators, which predominantly utilize teacher-focused methodologies.

The low level of students' critical thinking skills may be influenced by several factors, such as inappropriate learning models and teaching media (Kurniati et al., 2022). Learning models and teaching media complement each other in creating effective learning experiences. Suitable media help students organize unstructured information, thereby supporting more effective learning outcomes (Kilroy, 2004).

There are many ways educators can develop students' critical thinking skills, one of which is by using appropriate learning models in the learning process. One of the recommended learning models in the "Kurikulum Merdeka" is Problem-Based Learning (PBL). According to research conducted by Damayanti (2023), a well-implemented and engaging PBL model encourages students to actively think during the learning process. The steps involved in the PBL model also provide opportunities for students to think critically in solving problems.

The implementation of a learning paradigm centered on the student is deemed crucial, given that science education, particularly in physics, ought to extend beyond mere conceptual and factual knowledge to incorporate students' personal experiences, thereby facilitating their scientific understanding (Rahmadita et al., 2021). A particular subject matter in physics suitable for the enhancement of critical thinking skills is the study of rotational dynamics. Critical thinking skills are crucial for understanding motion-related topics as they require strong reasoning abilities and serve as a prerequisite for learning subsequent physics concepts.

Based on a preliminary study conducted by interviewing a physics teacher at a high school in Bandung, physics learning still relies on simple and conventional methods, where the teacher is the central figure in the learning process. The teacher mentioned that students' critical thinking skills are still considered low, as indicated by an average physics midterm score of 54.20, whereas the minimum passing grade is 76. This was further supported by a preliminary critical thinking test on rotational dynamics conducted by the researcher, which has an average score of 46.2. Additionally, the teacher stated that laboratory-based physics experiments are rarely conducted due to the limited availability of laboratory equipment. However, it was noted that internet access is available in every classroom.

---

As an alternative solution to the lack of experimental tools, schools can utilize interactive web-based simulation applications such as Physical Education and Technology (PhET), developed by the University of Colorado. This application has been widely used by educators and students worldwide (Fuada et al., 2023). PhET can serve as a substitute for real laboratories, as it provides models and simulations that facilitate students' understanding of concepts (Astalini, 2019). Research by Zahara et al. (2015) revealed that the use of PhET (Physics Education Technology) in learning can improve students' academic performance and critical thinking skills. Similarly, study by Stiawan et al. (2014) demonstrated that the use of PhET enhances students' critical thinking skills, with the most dominant critical thinking indicator being argument analysis. Ramadan et al. (2020) also found a significant impact of using PhET simulations in problem-based learning to improve students' critical thinking skills. Learning with PhET simulations enables students to observe, engage in deeper learning, and gain meaningful learning experiences.

Existing research demonstrates that the utilization of a problem-based learning model, when combined with PhET simulations, has a favorable effect on the development of students' critical thinking proficiencies and their learning results. Aisyah et al. (2024) concluded that the PBL model assisted by PhET in wave mechanics significantly enhances students' critical thinking skills compared to conventional learning. Similar findings were reported by Tiyas et al. (2024), where the use of the PBL model assisted by PhET in momentum and impulse material increased the post-test average score by 15%, with critical thinking skills categorized as good and student participation categorized as moderately active and active in each session. Based on the background that are mentioned, the researcher implements the Problem-Based Learning model assisted by PhET Simulations, which is expected to enchases students' critical thinking skills, particularly in rotational dynamics.

## 2. Methodology

A quantitative approach is adopted in this study, and the research design implemented is a Quasi-experimental design featuring a Non-equivalent control group. Therefore, the study involves the use of an experimental class alongside a comparative class, or control class. The experimental class will experience a problem-based learning model supported by PhET simulations, whereas the control class will be taught via a problem-based learning model lacking the support of PhET simulations. The scheme of research that will be applied can be seen in Table 1.

Table 1. Scheme of Research

Group	Pretest	Treatment	Posttest
Experiment	$O_1$	$X_1$	$O_2$
Control	$O_1$	$X_2$	$O_2$

(Sugiyono, 2013)

Information:

$O_1$ : Pre-test in Experimental and Control Class

$X_1$ : Treatment using Problem-Based Learning Model Assisted by PhET Simulations

$X_1$ : Treatment using Problem-Based Learning Model

$O_2$ : Post-test in Experimental and Control Class

This research involved students, teacher, and observer as participants. The population consisted of 11<sup>th</sup>-grade high school students in school at Bandung. The experimental class consisted of 33 students, while the control class consisted of 32 students. To assess students' critical thinking skills, a pre-test and post-test were administered to both groups. The test items were developed based on critical thinking indicators by Facione (1990), focusing on interpretation, analysis, evaluation, inference, and explanation within the context of rotational dynamics. The instrument's validity and reliability were tested using Rasch model analysis. Additionally, student worksheets, observation sheets, and students' response sheets were used to support qualitative analysis of students' engagement and learning experiences with PhET simulations in the PBL framework.

The gathered information was subjected to analysis via SPSS 27.0, utilizing multiple statistical assessments to establish the degree to which the Problem-Based Learning (PBL) model, with the integration of PhET simulations, contributed to the enhancement of students' critical thinking skills. The analysis steps were as follows:

### ***Normality Test***

A preliminary step before undertaking hypothesis testing involved a normality test to verify if the data adhered to a normal distribution. The Shapiro-Wilk test was employed in this context because the sample size within each student group was less than 50. The level of significance (p-value) for this assessment was fixed at 0.05:

- If  $p\text{-value} > 0.05$ , the data were normally distributed.
- If  $p\text{-value} < 0.05$ , the data were not normally distributed, and a non-parametric test was required.

### ***Hypothesis Test***

To determine whether there was a significant difference in students' critical thinking improvement between the experimental and control groups, the following tests were conducted:

- Independent Sample T-Test (if data were normally distributed) → To compare the mean difference in pre-test and post-test scores between the two groups.
  - Mann-Whitney U Test (if data were not normally distributed) → A non-parametric alternative to compare the differences in scores.
-

### ***N-Gain Calculation***

To measure the improvements on students' critical thinking skills based on the intervention, the N-Gain Score was calculated for both groups using the formula:

$$\text{N Gain Score} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal Score} - \text{Pretest Score}}$$

The N-Gain results were classified into three categories as seen on Table 2:

Table 2. N-Gain Score Categories

<b>N-Gain Score</b>	<b>Categories</b>
<b><math>g &gt; 0,70</math></b>	High
<b><math>0,70 \geq g \geq 0,30</math></b>	Medium
<b><math>g \leq 0,30</math></b>	Low

(Hake, 1999)

### **3. Result and Discussion**

The research was conducted in two classes, namely the experimental class and the control class, as assigned by the school. The experimental class received instruction through the Problem-Based Learning (PBL) model assisted by PhET simulations, while the control class followed conventional instruction using lectures and problem-solving exercises. The study was implemented over four meetings, covering initial orientation, presentation of real-world problems, concept exploration through simulation, group discussion, as well as presentation and reflection sessions.

In each meeting of the experimental class, students were introduced to a contextual problem that served as a stimulus for investigation. They were then guided to explore solutions using the PhET interactive simulation. The teacher acted as a facilitator, providing scaffolding as needed. During the activities, students used student worksheets (LKPD) to help them organize information, formulate hypotheses, and draw conclusions both independently and collaboratively.

The image below illustrates one of the learning activities in which students use the PhET simulation on rotational motion. In this session, students explored the effect of mass distribution on rotational speed using a spinning chair model. By adjusting variables such as arm position and mass placement, they were able to visualize the concept of moment of inertia and angular momentum in a dynamic, interactive way. This activity encouraged students to think critically about the physical phenomena they observed and to communicate their reasoning in group discussions.



Figure 1. Students Interacting with the PhET Simulation on Rotational Motion During Class

Using SPSS 27.0, the output of the data analysis provides insights into the effectiveness of the Problem-Based Learning (PBL) model assisted by PhET simulations in enhancing students' critical thinking skills. The results include normality testing, hypothesis testing, and N-Gain analysis to determine the statistical significance and learning improvement between the experimental and control groups.

### ***Normality Test Result***

The Shapiro-Wilk test was conducted on post-test scores in both classes to determine whether the data were normally distributed. Using SPSS 27.0, the output shows as seen in Table 3:

Table 3. Normality Test Result

<b>Data</b>	<b>Experiment Class</b>	<b>Control Class</b>
<b>N</b>	33	32
<b>Mean</b>	63.40	50.9
<b>Sig.</b>	0.438	0.169

The experimental group has a significance value (p-value) of 0.438, which is greater than the 0.05 significance, indicating a normal distribution (p-value > 0.05). The control class has a significance value (p-value) of 0.168, which is greater than the 0.05 significance value, indicating a normal distribution (p-value > 0.05). Since both the experiment and control class have a normal distribution, the Independent T-test was used for hypothesis testing instead of the Mann-Whitney U.

### ***Hypothesis Test Result***

The hypothesis used in this research is:

- **$H_0$** : There is no significant difference in improving students' critical thinking skills between the experimental class and the control class

- $H_a$ : There is a significant difference in improving students' critical thinking skills between the experimental class and the control class.

Using a significance level of 0.05, the significance value obtained will be interpreted based on Table 4:

Table 4. Interpretation of Hypothesis Test

Sig.	Interpretation
<0.05	$H_0$ is rejected and $H_a$ is accepted
>0.05	$H_0$ is accepted and $H_a$ is rejected

The independent samples t-test, conducted using SPSS version 27.0, yielded an output p-value of 0.009. Given that 0.009 is less than the established significance level of 0.05, the  $H_0$  hypothesis was rejected, and the  $H_a$  hypothesis was accepted. From this result, it is concluded that a statistically significant difference exists in the enhancement of students' critical thinking skills between the experimental and control instructional groups.

### *N-Gain Analysis Result*

To see how the improvement of students' critical thinking skills on each learning model that was applied, the n-gain is done by using SPSS 27.0, and the output of the test will be interpreted based on Table 2 and the result of interpretation is shown in Table 5:

Table 5. Results of N-Gain Test

Class	N-Gain	Categories
Experiment	0.4677	Medium
Control	0.2798	Low

Based on the output that was obtained from the SPSS 27.0 and based on the interpretation result, we can infer that overall, the experiment class using the problem-based learning model assisted by PhET simulation can increase students' critical thinking skills with the category "Medium". Despite the capacity of the problem-based learning model, when used by the control class without the aid of PhET simulation, to foster students' critical thinking skills, the level of this enhancement was categorized as "Low".

An examination of the calculated mean normalized gain (N-Gain) for all students on each question item reveals the extent of improvement in their critical thinking skills within each defined indicator. The results of the calculation of the average n-gain on each indicator are presented in Table 6. Based on Table 6, N-Gain on each indicator indicates an increase of critical thinking skills in the category "Medium." Within the control group, the critical thinking skill indicators of interpretation, evaluation, and explanation demonstrated an improvement to the "Medium" category, whereas the indicators of analysis and inference showed an increase only to the "Low" category.

Table 6. Mean N-Gain on Critical Thinking Skills Indicator

Critical Thinking Skills Indicator	Experiment Class		Control Class	
	N-Gain	Category	N-Gain	Category
Interpretation	0.51	Medium	0.31	Medium
Analysis	0.31	Medium	0.16	Low
Evaluation	0.62	Medium	0.40	Medium
Inference	0.42	Medium	0.22	Low
Explanation	0.58	Medium	0.48	Medium

To visualize the comparison of n-gain on each indicator in experimental and control class, a bar chart is presented in Figure 2.

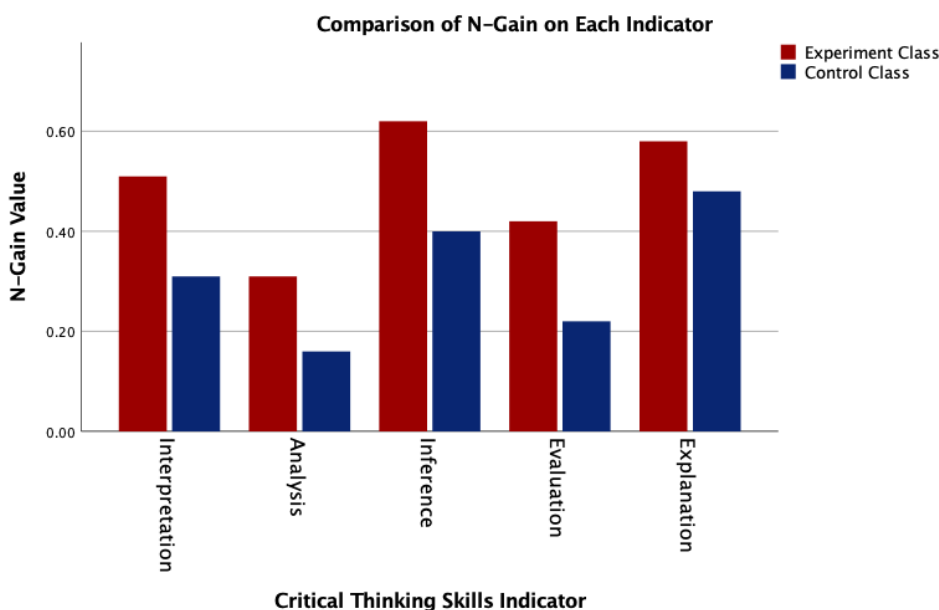


Figure 2. Comparison of N-Gain on Each Indicator

Referring to Figure 1, the normalized gain (N-Gain) score of the experiment class demonstrates superiority over the control class in all measured indicators. Therefore, it is reasonable to conclude that the advancement of students' critical thinking skills in each indicator within the experiment class, employing problem-based learning with PhET simulation assistance, was more significant than that observed in the control class, which utilized problem-based learning without the aid of PhET simulation.

The use of PhET simulations in learning has been shown to enhance students' critical thinking skills. Through these simulations, students are encouraged to analyze, evaluate, and draw conclusions based on the information they explore (Dy et al., 2024). In the control class, although the Problem-Based Learning model was implemented, students' learning experiences were still limited to text-based materials and group discussions, resulting in less consistent and generally lower improvement in critical thinking skills. A similar finding was reported by Zulianti (2024), who found that students in the experimental class using Problem-Based

Learning supported by PhET multimedia simulations showed greater improvement in critical thinking skills compared to those in the control group.

Furthermore, Salsabila et al. (2023) demonstrated that the experimental class using the PBL model with PhET simulations achieved a moderate category of critical thinking skill improvement, while the control class only reached the low category. This was attributed to the use of virtual laboratories such as PhET, which can increase students' interest and motivation, thereby encouraging the development of critical thinking in solving problems (Suranti et al., 2016). Students are enabled to hypothesize, experiment, and formulate solutions to problems based on the observed phenomena (Aca & Sulisworo, 2020). In other words, the synergy between the Problem-Based Learning model and PhET simulations creates an environment that actively engages students in the learning process, leading to the enhancement of their critical thinking abilities (Haetami et al., 2023).

#### **4. Conclusion**

This research was implemented in one of the schools in Bandung. The approach of this research is a quantitative approach with a Quasi-experimental design with a Non-equivalent control group design. Data analysis that was collected was performed using SPSS 27, including normality tests, hypothesis tests, and n-gain calculations for each critical thinking indicator. This research has proven that the Problem-Based Learning (PBL) model assisted by PhET simulations significantly enhances students' critical thinking skills in rotational dynamics material. Analysis using the independent t-test, a parametric method, demonstrates a significant distinction between the experimental class, instructed with a problem-based learning model aided by PhET simulation, and the control class, which received only problem-based learning without PhET simulation.

The experimental class exhibited a more noteworthy improvement in the critical thinking skills of its students. The increase in critical thinking indicators, which are interpretation, analysis, evaluation, inference, and explanation—was more increased in the experimental group, all of the indicators are in the medium category, while the control group showed mixed results, with interpretation, evaluation, and explanation are in the medium category and analysis and inference in the low category. Based on the result, we can conclude that the use of a problem-based learning model assisted by PhET simulation can increase students' critical thinking skills in the medium category. The findings of this research suggest that integrating interactive simulations with student-centered learning strategies helps students enhance their critical thinking skills. Educators are encouraged to implement these methods to enhance critical thinking and engagement in physics learning. Future research could explore the long-term impact of this approach on students' other skills, such as problem-solving abilities.

---

---

## References

- Aca, A. L., Sulisworo, D., & Maruto, G. (2020). The critical thinking skills impacts on the utilization of PhET simulation in the flipped classroom setting. *Proceedings of the International Conference on Community Development (ICCD 2020)*. Atlantis Press. <https://doi.org/10.2991/assehr.k.201017.024>
- Aisyah, S. N., Kosim, K., Gunawan, G., & Gunada, I. W. (2024). The effect of problem-based learning model assisted by PhET media on students' critical thinking skills. *Indonesian Journal of STEM Education*, 6(2), 86–101.
- Astalini, A., Darmaji, D., Riantoni, C., & Susanti, N. (2019). Studi penggunaan PhET Interactive Simulations dalam pembelajaran fisika. *Jurnal Riset Dan Kajian Pendidikan Fisika*, 6(2), 71. <https://doi.org/10.12928/jrkpf.v6i2.14202>
- Basri, H., Purwanto, P., As'ari, A., & Sisworo, S. (2019). Investigating critical thinking skill of junior high school in solving mathematical problem. *International Journal of Instruction*, 12(3), 745-758. <https://doi.org/10.29333/IJI.2019.12345A>
- Damayanti, E., Yuliyanti, R., Najiah, M., & Nulhakim, L. (2023). Improving critical thinking skills in thematic learning with the help of problem learning models. *Jurnal Penelitian Pendidikan IPA*, 9(7), 276–282. <https://doi.org/10.29303/jppipa.v9i7.3689>
- Dy, A. U., Lagura, J. C., & Baluyos, G. R. (2024). Using PhET Interactive Simulations to improve learners' performance in science. *EduLine: Journal of Education and Learning Innovation*, 4(4), 520-530. <https://doi.org/10.35877/454RI.eduline2981>
- Facione, P. A. (2011). Critical thinking: What it is and why it counts. *The California Academic Press*.
- Fuada, S., Danuarteu, M. D., Agustin, S., Carmelya, A. A., Fadhillah, I., Heong, Y. M., & Kaewpukdee, A. (2023). Can PhET simulate basic electronics circuits for undergraduate students?. *Jurnal Infotel*, 15(1), 97–110. <https://doi.org/10.20895/infotel.v15i1.861>
- Haetami, A., Zulvita, N. ., Dahlan, Maysara, Marhadi, M. A. ., & Santoso, T. . (2023). Investigation of Problem-Based Learning (PBL) on Physics Education Technology (PhET) Simulation in Improving Student Learning Outcomes in Acid-Base Material . *Jurnal Penelitian Pendidikan IPA*, 9(11), 9738–9748. <https://doi.org/10.29303/jppipa.v9i11.4820>
- Kurniati, I., Yuliani, Y., Suyono, S., & Mahroini, Z. (2022). Critical thinking skills students on solar system material. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 11(2), 130–141. <https://doi.org/10.26740/jpps.v11n2.p130-141>
- Mardhiyah, R. H., Aldriani, S. N. F., Chitta, F., & Zulfikar, M. R. (2021). Pentingnya keterampilan belajar di abad 21 sebagai tuntutan dalam pengembangan sumber daya manusia. *Lectura: Jurnal Pendidikan*, 12(1), 29–40. <https://doi.org/10.31849/lectura.v12i1.5813>
- Rahmadita, N., Mubarak, H., & Prahani, B. K. (2021). Profile of problem-based learning (PBL) model assisted by PhET to improve critical thinking skills of high school students in dynamic electrical materials. *Jurnal Penelitian Pendidikan IPA*, 7(4), 617–624. <https://doi.org/10.29303/jppipa.v7i4.799>
-

- Raj, T., Chauhan, P., Mehrotra, R., & Sharma, M. (2022). Importance of critical thinking in the education. *World Journal of English Language*, 12(3), 126–133. <https://doi.org/10.5430/wjel.v12n3p126>
- Ramadan, E. M., Jumadi, & Astuti, D. P. (2020). Application of e-handout based on PhET simulation to improve critical thinking skills and learning independence of high school students. *Journal of Physics: Conference Series*, 1440(1), 0–7. <https://doi.org/10.1088/1742-6596/1440/1/012025>
- Salsabila, N., Suryandari, K. C., & Salimi, M. (2023). The effect of pbl assisted by PhET simulation on critical thinking skills in class VI science learning at elementary schools in the banyumudal cluster, kebumen regency, academic year 2022/2023. *SEEDS: Science, Engineering, and Development Studies*, 7(1), 12-18. <https://doi.org/10.20961/seeds.v7i1.80909>
- Sarwanto, Fajari, L. E. W., & Chumdari. (2021). Critical thinking skills and their impacts on elementary school students. *Malaysian Journal of Learning and Instruction*, 18(2), 161–187. <https://doi.org/10.32890/mjli2021.18.2.6>
- Stiawan, E., Liliyasi, L., & Rohman, I. (2014). Pengembangan keterampilan berpikir kritis siswa SMA pada topik teori domain elektron melalui simulasi interaktif PhET molecule shapes. *Jurnal Pengajaran Matematika Dan Ilmu Pengetahuan Alam*, 19(2), 257. <https://doi.org/10.18269/jpmipa.v19i2.468>
- Suranti, N. M. Y., Gunawan, G., & Sahidu, H. (2016). Pengaruh Model Project Based Learning berbantuan Media Virtual terhadap Penguasaan Konsep Peserta Didik pada Materi Alat-Alat Optik. *Jurnal Pendidikan Fisika dan Teknologi*, 2(2), 73-79. <https://doi.org/10.29303/jpft.v2i2.292>
- Tiyas, S. I. R. N., Khusaini, K., & Purwantini, A. (2024). Analisis penerapan model pembelajaran problem-based learning (PBL) berbantuan media PhET di SMA Brawijaya Smart School Malang. *Jurnal Ilmiah Nusantara*, 1(4), 909-919. <https://doi.org/10.61722/jinu.v1i4.1991>
- Zahara, S., Yusrizal, Y., & Rahwanto, A. (2015). Pengaruh penggunaan media komputer berbasis simulasi Physics Education Technology (PhET) terhadap hasil belajar dan keterampilan berpikir kritis siswa pada materi fluida statis. *Jurnal Pendidikan Sains Indonesia*, 3(1), 251–258.
- Zulianti, W. (2025). Pengaruh Model Problem Based Learning Berbantuan Multimedia PhET Simulation terhadap Keterampilan Berpikir Kritis Siswa. *UNIEDU: Universal Journal of Educational Research*, 5(3), 133-147. <https://doi.org/10.1234/uniedu.v5i3.158>

How to cite this article:

Mustikazahra, F., Novia, H., & Aviyanti, L. (2025). Application of PhET Simulation-Assisted Problem-Based Learning Model in Improving Students' Critical Thinking Skills on Rotational Dynamics Material. *Journal of Educational Sciences*, 9(4), 1742-1752.