Problem-Based Learning (PBL) Activity with Phet Simulations: A Strategic Intervention Material in Teaching Impulse and Momentum

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ABSTRACT

Physics is a discipline that explains fundamental natural laws, enabling learners to connect abstract concepts with real-life phenomena. However, many students struggle with solving physics problems, particularly those involving impulse and momentum, due to limited conceptual understanding and persistent misconceptions. This study aimed to develop and implement a Problem-Based Learning (PBL) activity integrated with PhET simulations to improve Grade 9 learners' understanding of impulse and momentum. It also aimed to evaluate the effectiveness of the intervention based on student learning gains and perceptions of both teachers and learners. A needs assessment was first conducted among two sections of Grade 11 learners, which identified impulse and momentum as the not mastered competency. Utilizing a quasi-experimental one-group pretest-posttest design, the study measured students' learning gains and focused on addressing this competency. Standardized achievement tests were administered to eighty-three (83) Grade 9 students from a selected public high school in Iligan City. Results revealed a lack of mastery based on test scores, and the calculated normalized gain was 0.28, which falls within the low gain category according to Hake's (1999) classification. The PBL activity with PhET simulations significantly improved students' conceptual understanding of impulse and momentum. Students found the activity engaging, meaningful, and helpful in making complex physics concepts easier to understand, highlighting its effectiveness as a learning strategy.

Keywords: Conceptual Understanding, Impulse and Momentum, PhET Simulation, Physics Education, Problem-Based Learning

INTRODUCTION

Physics is a science that explains fundamental natural laws, helping learners connect complex concepts to daily life. It explains how things move, interact, and are influenced by forces. Many learners struggle with physics problems, especially impulse and momentum, due to factors like limited conceptual understanding, weak math skills, inadequate problem-solving practice, and low motivation in physics (Adianto & Rusli, 2021).

Most learners find physics challenging and uninteresting (Charli et al, 2018), with many disliking the subject despite its significance, as they struggle to grasp its complex concepts and fail to see its relevance to their lives (Rosdianto, 2018). Teachers rarely link physics to real-life applications, making it appear irrelevant to solving real-world problems after graduation (Sari et al., 2013). In practice, physics learning should adopt approaches that are more connected to real-world problems and everyday events (Shohimin, 2016).

Research shows that many learners perceive physics negatively due to its focus on memorizing formulas, lack of real-world applications, and reliance on traditional teaching methods like note-taking and problem-solving (Syarifah & Ritonga, 2020). The absence of real-life connections in lessons disrupts the learning process and makes achieving desired outcomes more challenging (Bao & Koenig, 2019). However, learners become more engaged when lessons are linked to everyday life (Syarifah & Ritonga, 2020).

Another study (Haqqo et al., 2023) reported that 42.86% of 34 learners had misconceptions, primarily due to false negatives and associative thinking, with 35.29% struggling with energy and momentum conservation in collisions. A similar analysis (Liwanag et al., 2022) of a 20-item test revealed misconceptions in 16 questions, with 69% mastering question 12. Misconception rates across momentum, impulse, their relationship, the law of conservation, and collisions ranged from 31% to 97%.

Addressing these challenges requires implementing an appropriate learning model, such as problem-based learning (PBL), which emphasizes solving meaningful problems rooted in everyday phenomena, making them easier for learners to understand (Phungsuk et al., 2017). This approach makes learning more relevant and enjoyable (Erda et al., 2018; Camacho & Christiansen, 2018). PBL not only enhances learners' understanding and physics performance but also develops their cognitive and reasoning skills, enabling them to analyze problems and create effective solutions (Suyatno, 2009; Mardian & Yerizon, 2018).

Learning media play a crucial role in facilitating learning activities and enhancing student outcomes (Widodo, 2018). With rapidly advancing technology, teachers are encouraged to utilize the use of interactive media which can be facilitate learners in learning physics concept (Rahmawati & Astuti, 2020) such as PhET simulation media (Paje et al., 2021; Banda & Nzabahimana, 2021). PhET applications are used to assist learners in understanding virtual concepts.

Research (Haetami et al., 2023) shows that integrating PBL with PhET simulations significantly improves student learning outcomes in acid-base materials, effectively enhancing conceptual understanding, critical thinking skills, and knowledge retention. Additionally, PhET simulations offer interactive models that aid in comprehending complex physics concepts and strengthening visual perception.

This study aligns with Sustainable Development Goal (SDG) 4: Quality Education, which aims to ensure inclusive and equitable education and promote lifelong learning opportunities for all. By integrating Problem-Based Learning (PBL) with PhET simulations, it enhances physics education by fostering critical thinking, problem-solving skills, and conceptual understanding—key competencies for 21st-century learning. The interactive and engaging nature of this approach supports global educational reform efforts that emphasize student-centered learning, technology integration, and real-world applications of knowledge.

Additionally, this study contributes to SDG 17: Partnerships for the Goals by promoting collaboration and the use of open educational resources in science education. By leveraging digital tools like PhET simulations and fostering cooperative learning environments, the research highlights the importance of partnerships between educators, researchers, and institutions in advancing innovative teaching strategies.

This study aimed to develop and implement a Problem-Based Learning (PBL) activity incorporating PhET simulations to enhance students' conceptual understanding of impulse and momentum. Specifically, it aimed to evaluate its effectiveness based on students' achievement gains and the perceptions of teachers and learners regarding the developed PBL activity.

METHODOLOGY

This study utilized a quasi-experimental one-group pretest-posttest design to assess learning gains in Grade 9 Physics after implementing a Problem-Based Learning (PBL) activity integrated with PhET simulations. The activity aimed to enhance students' conceptual understanding of impulse and momentum, a competency identified as not mastered based on a needs assessment taken by two sections of Grade 11 learners yielding a Cronbach's alpha of 0.771.

Purposive sampling was used to select participants for both intervention and evaluation. A 30-item researcher-made achievement test, aligned with the Department of Education's MELCs and validated by the adviser and panelists. The test showed good reliability yielding a Cronbach's alpha of 0.883 and was used for both pretest and posttest.

Data collection included pretest-posttest administration and perception surveys for students and teachers. The study was conducted in a selected public high school in Iligan City during the fourth quarter of SY 2024–2025, involving eighty-three (83) purposively chosen Grade 9 students from two sections. These students completed the PBL activity and assessments using pen-and-paper tests. To ensure validity, five (5) Physics teachers with at least five years of experience evaluated the activity. Ethical protocols were followed, including school approval, learner consent, voluntary participation, and confidentiality through anonymous coding.

RESULTS AND DISCUSSION

Table 1. Needs Assessment Reliability Coefficient

Cronbach Alpha	No. of Items	Interpretation
0.77071419	50	Acceptable

A 50-item needs assessment questionnaire was validated by three experts and subsequently administered. It underwent pilot testing and implementation procedures. The pilot testing was conducted with 150 Grade 10 students from a selected public high school in Iligan City, yielding a Cronbach's alpha of 0.77, which is interpreted as acceptable. This result indicated that the instrument was ready for the implementation phase.

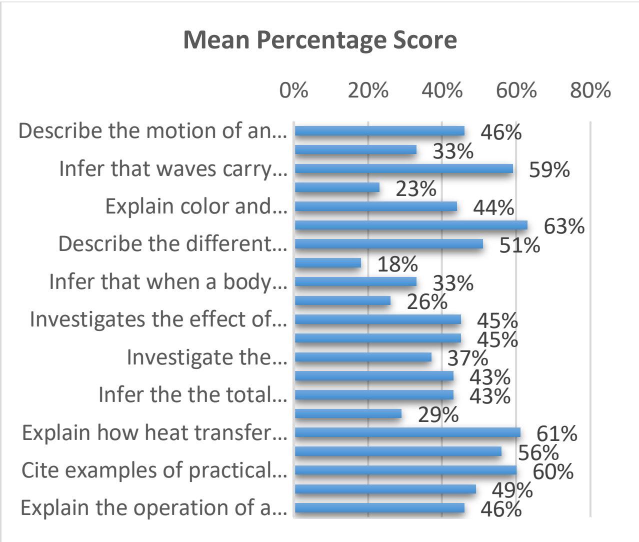

Figure 1. Mastery Level of Learners in Physics

Based on the results of the needs assessment conducted among ninety (90) Grade 11 students in a selected public high school in Iligan City, the overall performance of students across the identified physics competencies falls within the "Not Mastered" and "Least Mastered" levels, with no competency reaching the "Nearly Mastered" or "Mastered" categories. This indicates a general need for instructional reinforcement across all areas. In particular, the competency *"Infer that the total momentum before and after collision is equal"*, which encompasses the concepts of impulse and momentum, recorded a mean percentage score of 43%, placing it in the "Not Mastered" category. This result highlights a significant gap in students' understanding of fundamental physics concepts related to momentum conservation and the effects of impulse during collisions. Addressing this gap is essential for improving students' ability to analyze real-world phenomena involving motion and forces.

To enhance the learning of impulse and momentum concepts among Grade 9 students, a series of supplementary teaching activities were developed. These activities, designed in alignment with the K to 12 Basic Education Curriculum Guide, are detailed below.

This material consisted of two (2) supplementary teaching activities on impulse and momentum, developed in alignment with the learning competencies outlined in the K to 12 Basic Education Curriculum Guide. These were: Activity 1 – Investigating Momentum through Collisions, Activity 2 – Investigating Impulse, and a Culminating Activity – Solve the Crash Mystery Creatively. To ensure the effectiveness of the developed Problem-Based Learning (PBL) activities, they were evaluated by five (5) in-service teachers with at least five

(5) years of teaching experience in science subjects. Based on their feedback, necessary revisions were made to further refine and enhance the overall learning experience.

Table 2. Validation Result of the PBL Activity

CRITERIA	TEACHER A	TEACHER B	TEACHER C	TEACHER D	TEACHER E	MEAN	INTERPRETATION
Curriculum Relevance	5	5	5	5	5	5	Excellent
Activity Structure & Clarity	5	5	5	5	5	5	Excellent
Background Information & Objectives	5	5	5	5	5	5	Excellent
Inquiry & Critical thinking	5	5	5	5	5	5	Excellent
Engagement & Real-World Application	5	5	5	5	5	5	Excellent

Table 2 showed the validation results of the Problem-Based Learning (PBL) activity, which consisted of five (5) criteria. A highest score of 5 indicated that the activity was excellent and ready for implementation.

The effectiveness of these activities was then assessed through a pretest and posttest, with the results summarized in Table 3.

Table 3. Conceptual Understanding Gain Scores

No. of Respondents	Group	Mean Score	Normalized Gain
80	Pretest	13.55	0.28
	Posttest	18.23	

Based on the data presented in Table 3, a total of eighty (80) respondents participated in the study out of eighty-three (83) total learners of Grade 9, as three (3) were absent and were not able to take the posttest, with a mean pretest score of 13.55 and a mean posttest score of 18.23. This indicates an improvement in students' performance after the implementation of the learning activity on impulse and momentum. The calculated normalized gain is 0.28, which falls within the low gain category according to Hake's (1999) classification. While the improvement in scores suggests that learning did occur, the low normalized gain implies that the effect of the intervention on overall conceptual understanding was limited. Nonetheless, the increase in posttest scores shows that the activity had some positive impact on students' learning outcomes

Table 4. Summary of Students' Perceptions on PBL Activity

Statement	Mean Score	Interpretation
I believe that participating in the activities has increased my interest in the lesson.	3.36	Strongly Agree
I feel the activities help us connect to real-life situations effectively.	3.28	Strongly Agree
I think the activities are helping me develop skills in teamwork, communication, and collaboration.	3.38	Strongly Agree
I thoroughly enjoy participating in the activities.	3.19	Agree
In my view, the activities are essential for my growth because they encourage me to seek more information and ask questions.	3.14	Agree
The activities help us cultivate positive values and character.	3.11	Agree
I believe the activities challenge me to excel and give my best effort.	3.25	Strongly Agree
Through the activities, I have developed new self-regulated learning strategies, such as note-taking, sharing ideas, and conducting further research.	3.2	Agree
I engaged in the activities because I genuinely enjoyed and wanted to do them.	3.05	Agree
I believe these activities inspire me to improve because they emphasize practical lessons for the future rather than just focusing on grades.	3.18	Agree
I think the activities helped me understand the importance of being cautious about road and sports safety, which my family and I face every day.	3.29	Strongly Agree
I'm open to participating in both small and large group activities because they help me stay open-minded.	3.14	Agree
I'm really interested in the activities because they allowed me to learn from my teacher, classmates, books, and even the internet.	3.21	Agree
While participating in the activities, I felt that I developed the value of being mindful and careful about my actions and decisions.	3.18	Agree
The online simulations, along with the science terms and words, were easy to understand since I am familiar with them from real life.	2.98	Agree
I would describe the activity as very enjoyable because I could relate to the experiences shared by my classmates.	3.05	Agree
I would be willing to do the activity again because it holds value for me.	3.13	Agree
Through large group activities, I realized that even if we have different ideas, we can succeed by working together as a team.	3.38	Strongly Agree
I would describe the activities as challenging and difficult.	1.94	Disagree
The activities are relatively easy because the examples used are common situations in road and sports events.	3.08	Agree
Total	3.12	Agree

Table 4 showed the summary of students' perceptions based on twenty (20) statements, indicating the mean scores and their respective interpretations. The overall mean score was 3.12, which corresponds to "Agree." This result implied that the students found the activity engaging, meaningful, and helpful in making complex physics concepts easier to understand, highlighting its effectiveness as a learning strategy.

Table 5. Summary of Teachers' Perceptions on PBL Activity

Category	Average Mean	Interpretation
Usability	4	Highly Usable
Acceptability	4	Highly Acceptable

Based on Table 5, the teachers' perceptions of the PBL activity indicated that it was highly usable and highly acceptable. This suggests that the material effectively met instructional standards and learning objectives, making it suitable for classroom use. As a result, the teachers recommended the use of this PBL activity in future physics lessons to enhance student engagement and understanding of complex concepts.

CONCLUSION

The study assessed the mastery level of Grade 11 learners in selected Physics competencies. Results showed that learners fell under the "Not Mastered" category (≤50%), with key competencies such as *inferring action-reaction forces, explaining light properties,* and especially *inferring momentum before and after collisions* (mean score: 43%) requiring attention. The mastery level of Grade 11 reflected a lack of mastery. This was supported by achievement test results, where eighty (80) learners demonstrated a normalized gain of 0.28, which was classified as low gain, indicating limited improvement after instruction.

To address these gaps, a Problem-Based Learning (PBL) activity integrated with the PhET Collision Lab simulation was implemented. Through this approach, students explored real-world scenarios involving collisions, which allowed them to investigate key variables such as mass and velocity. The simulation enabled them to visualize and manipulate these variables, which helped them understand how momentum and impulse were affected during collisions. This hands-on experience supported students in constructing deeper conceptual understanding by actively engaging in inquiry, analysis, and evidence-based reasoning.

Although the overall gain remained low, the results suggested that the PBL activity had provided a meaningful learning experience and contributed to a better grasp of complex physics concepts. The modest improvement observed indicated that even a short-term PBL intervention helped improve students' conceptual understanding. Future studies were recommended to consider longer implementation periods, teacher training in PBL strategies, and diversified assessment methods to maximize the impact of such innovative approaches in physics education.

REFERENCES

1. Adianto, T., & Rusli, M. A. (2021). Analysis of Studentâ€™ s Difficulties in Solving Physics Problem: Impulse and Momentum Topics. Unnes Science Education Journal, 10(1), 24-33.
2. Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on learners' conceptual understanding in physics: A review of literature. Physical review physics education research, 17(2), 023108.
3. Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. https://doi.org/10.1186/s43031-019-0007-8
4. Camacho, H., & Christiansen, E. (2018). Teaching Critical Thinking within an Institutionalised Problem Based Learning Paradigm--Quite a Challenge. Journal of Problem based learning in Higher Education, 6(2), 91-109.
5. Charli, L., Amin, A., & Agustina, D. (2018). Kesulitan siswa dalam menyelesaikan soal fisika pada materi suhu dan kalor di kelas x sma ar-risalah lubuklinggau tahun pelajaran 2016/2017. Journal of Education and Instruction (JOEAI), 1(1), 42-50.

6. Erda, V., Razak, A., & Sumarmin, R. (2018). The Effect of Model Problem Based Learning of Learning Outcomes Student Course on Animal Ecology Based on Learning Styles. International Journal of Progressive Sciences and Technologies, 538(2), 533-538.
7. Haetami, A., Zulvita, N., 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.
8. Haqqo, A., Yuliati, L., & Latifah, E. (2023, January). Exploration of learners' conceptual changes through phenomenon based distance learning with multimedia videos momentum and impulse. In AIP Conference Proceedings (Vol. 2569, No. 1). AIP Publishing.
9. Liwanag, M., Salic-Hairulla, M., Malicoban, E. V., Alcuizar, R. M., Villaruz, M., & Malayao, S. J. (2022). A Development of Comprehensive Project-Based Learning Packets in Teaching Conservation of Momentum. International Journal of Science Education and Teaching, 1(3), Article 3.
10. Mardian, E., & Yerizon. (2018). Validity of Problem Based Learning Oriented Learning Tools For Senior High School. *International Journal of Progressive Sciences and Technologies*, *10*(1), 96–102.
11. Paje, Y. M., Rogayan Jr, D. V., & Dantic, M. J. P. (2021). Teachers' Utilization of Computer-Based Technology in Science Instruction. International Journal of Technology in Education and Science, 5(3), 427-446.
12. R Phungsuk, R., Viriyavejakul, C., & Ratanaolarn, T. (2017). Development of a problem-based learning model via a virtual learning environment. Kasetsart Journal of Social Sciences, 38(3), 297-306.
13. Rahmawati, E. N., & Astuti, D. P. (2020). Development of e-handout assisted by PhET simulation with problem based learning (PBL) model about momentum conservation law and collision to train learners' conceptual understanding. In Journal of Physics: Conference Series (Vol. 1440, No. 1, p. 012048). IOP Publishing.
14. Rosdianto, H. (2018). Implementasi model pembelajaran POE (predict observe explain) untuk meningkatkan pemahaman konsep siswa pada materi hukum Newton.
15. Sari, D. M., Surantoro, S., & Ekawati, E. Y. (2013). Analisis kesalahan dalam menyelesaikan soal materi termodinamika pada siswa SMA. Jurnal Materi dan Pembelajaran Fisika, 3(1).
16. Shohimin. (2016). *Model Pembelajaran Inonvatif dalam Kurikulum 2013*. Yogyakarta: Ar-Ruzz Media. simulation and learning new skills in video-assisted thoracic surgery. Video- Assisted Thoracic Surgery, 3, 35–35.
17. Suyatno. (2009). *Menjelajah Pembelajaran Inofatif*. Sidoarjo: Masmedia Buana Pustaka.
18. Syarifah, R., & Ritonga, W. (2020). Application of problem based learning model on student learning outcomes on momentum and impulse materials. IPER (Indonesian Physics Education Research), 1(1), 19-26.
19. Widodo, S. A. (2018). Selection of Learning Media Mathematics for Junior School Learners. Turkish Online Journal of Educational Technology-TOJET, 17(1), 154-160.