



DEVELOPMENT AND VALIDATION OF A PROBLEM-BASED LABORATORY MANUAL IN GENERAL PHYSICS

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ABSTRACT

This study aimed to develop and validate a set of problem-based laboratory manuals in General Physics for Grade 12 students in the Science, Technology, Engineering, and Mathematics (STEM) strand. The laboratory manual designed by the researcher assisted students in performing experiments while enhancing their understanding and skills in Physics. Specifically, the manual focused on improving student performance in the General Physics subject. The experiments were crafted to help students apply conceptual knowledge to practical, real-world scenarios, while fostering critical thinking, problem-solving, creative thinking, and decision-making skills. Additionally, the manual guided students in grasping fundamental physics concepts, understanding measurement limitations, and working with complex experimental instruments. The study involved an experimental group of students who used the problem-based laboratory manuals. A pre-test was conducted before the experiment, and a post-test was administered afterward to assess the students' progress. The results revealed that students who used the problem-based manuals showed significant improvement in General Physics. They also demonstrated more positive attitudes and greater interest in learning the subject through this approach. However, challenges arose during implementation, as some students were unfamiliar with certain topics and encountered difficulties in the problem-solving process. These issues required teachers to invest additional time and effort in preparing and delivering the problem-based activities effectively.

KEYWORDS: *Development and Validation, General Physics, Problem-Based Laboratory Manual, Higher-order Thinking Skills, Learning Attitude*

INTRODUCTION

Science learning flourishes through hands-on and mind-on experimentation, but without structured laboratory manuals, practical activities can be difficult (Mercado, 2020). Problem-Based Learning (PBL) offers a solution by engaging students in real-world problems that activate prior knowledge, integrate disciplines, and foster critical thinking, reflection, and self-directed learning (Chua et al., 2016).

This study explored laboratory work among senior high school science students and their openness to independent investigations through PBL. Laboratory activities develop cognitive skills, reasoning, independence, and appreciation of science (NARST, 2018). To address challenges in Physics education—such as limited resources and time constraints—a problem-based laboratory manual was designed and validated for General Physics instruction.

Global research supports PBL-based laboratory instruction: Park et al. (2019) in South Korea improved understanding of electrical concepts; Suryanda et al. (2019) in Indonesia created mobile manuals to address resource gaps; and Kemeza et al. (2022) in Uganda showed PBL's role in bridging comprehension gaps and boosting participation. These examples highlight PBL's adaptability across contexts.

Beyond concept mastery, laboratory learning enhances skills in data interpretation, collaboration, and problem-solving (Kirschner & Meester, 1988). PBL further develops transferable competencies—teamwork, communication, and analytical reasoning—vital for academic and workplace success. Yet, resource limitations and

institutional disruptions persist (Naval, 2014), underscoring the need for adaptable manuals that uphold PBL principles.

This study contributes to Physics education by designing and validating a problem-based laboratory manual with structured inquiry tasks, experimental protocols, and guided discussions. By linking theory with practice, the manual aims to spark curiosity, strengthen critical thinking, and deepen application of Physics concepts, creating a more engaging learning experience for senior high school students.

Research Questions

The study aimed to develop and validate a problem-based laboratory manual in general physics.

1. How is the process of development of the Problem-Based Laboratory Manual in General Physics?
2. What are the pretest and post-test scores of the students exposed to the Problem Based Learning Laboratory Manual in Physics?
3. Is there a significant difference in the pre-test and post-test scores the students exposed to the Problem Based Learning Laboratory Manual in Physics?
4. What is the level of Higher-Order Thinking Ability of the students in General Physics in the experimental group before and after their exposure to the Problem Based Learning Laboratory Manual in Physics in terms of the following?
 - 4.1 Critical Thinking
 - 4.2 Creative Thinking
 - 4.3 Decision Making
 - 4.4 Problem Solving



5. What is the attitude of students in Physics before and after their exposure to the Problem Based Learning Laboratory Manual?
6. Is there a significant difference in the attitude of students in Physics before and after their exposure to the Problem Based Learning Laboratory Manual?
7. What are the Problems and Challenges encountered by Students using the Problem-Based Manual in Physics?

METHOD

Research Design

This study employed a product-oriented experimental design using a one-group pre-test/post-test format to evaluate the effectiveness of the Physics Problem-Based Laboratory Manual. The same group of students was assessed before and after implementation to measure gains in engagement and conceptual understanding. The manual promoted active learning through real-life problem scenarios, hands-on experiments, and inquiry-based tasks aligned with Physics competencies. Confounding variables such as prior knowledge and instructional conditions were monitored to strengthen validity.

Research Respondents

The respondents were 25 STEM senior high school students from St. Mary's College of Tagum Inc. (AY 2023–2024). They completed the pre-test, used the validated manual, and then took the post-test. Content experts comprising the school principal, senior high focal person, and science subject head evaluated the manual before and after refinement. Students then conducted laboratory experiments using the finalized manual.

Research Instruments

Six instruments were employed to evaluate the effectiveness of the Physics Problem-Based Laboratory Manual. The Interview Guide was used to identify student difficulties in using the manual, while the Expert Evaluation Tool (five-point Likert scale; Torre Franca, 2017) assessed its scientific validity. The Attitude and Interest Questionnaire (Cheung, 2011) measured changes in students' attitudes toward

Physics before and after exposure to the manual. To assess cognitive skills, the Higher-Order Thinking Ability Questionnaire (adapted from Geng, 2022) evaluated problem-solving, decision-making, and creative thinking through 43 items on a 5-point scale. Finally, the General Physics Achievement Test, a 100-item multiple-choice exam covering specific topics in General Physics.

Statistical Treatment of Data

Mean. This was used to analyze the level of the attitude of the students toward General Physics as well as to analyze the performance of the students in General Physics before and after exposure to the PBL Laboratory Manual in Physics.

Paired Samples t-Test. This was used to determine whether there was a significant difference between the students' attitude toward General Physics, and Experimental group mean scores before and after the intervention.

RESULTS

The ADDIE Model

A well-established instructional design framework guided the creation of the game-based performance tasks through five stages—Analysis, Design, Development, Implementation, and Evaluation—ensuring alignment with educational goals and cognitive principles. Using this model, the Problem-Based Laboratory Manual in Physics was developed as a learner-centered tool that addressed gaps in traditional instruction by fostering engagement, real-world application, and inquiry-driven problem-solving. Grounded in national curriculum standards, Cognitive Load Theory, and constructivist principles, the manual included structured components such as motivation, problem-based tasks, reflection, and assessment to build higher-order thinking. Development involved pilot testing, refinement, and teacher support materials for adaptability. Implementation showed improved student engagement, mastery, and collaboration, while evaluation confirmed its effectiveness in managing cognitive load and enhancing scientific reasoning. Expert validation affirmed its potential to transform Physics instruction into an active, inquiry-driven experience.



Figure 1. The ADDIE Model for the Refinement of the Game-based Performance Tasks



Table 1. Pre-test and Post-test Scores of the Experimental Groups in the General Physics Achievement Test

Score Range	Experimental Group			
	Pre-Test		Post-Test	
	F	P	F	P
Excellent (91-100)	-	-	-	-
Very Good (81-90)	-	-	-	-
Good (71-80)	-	-	1	4
Satisfactory (61-70)	-	-	15	60
Passed (51-60)	1	4	8	32
Failed (50 and below)	24	96	1	4
Total	25	100	25	100
Mean	43.12		63.88	

The results show a clear improvement in student performance after using the Problem-Based Laboratory Manual in Physics. The mean pre-test score of 43.12 (Failed) rose to 63.88 (Satisfactory) in the post-test, indicating enhanced mastery of Physics concepts. This suggests that the manual effectively facilitated better understanding and achievement,

supporting the value of problem-based approaches in fostering critical thinking, real-world problem-solving, and active participation. Consistent with Wynn (2022), the findings affirm that PBL creates meaningful learning experiences and empowers students to engage more deeply with complex subjects like Physics.

Table 2. Significant Difference in the Pre-test and Post-test of the Student Participants Exposed to the PBL Laboratory Manual in General Physics

Experimental Group	Mean	SD	t-test	P-value	Decision at 0.05
Before	43.12	5.10	2.783	0.010	Reject H_0
After	63.88				

Table 6 shows that the probability value of 0.010 is below the 0.05 significance level, leading to the rejection of the null hypothesis. This confirms a significant difference between

the pre-test and post-test scores, indicating that student performance in General Physics improved notably after using the Problem-Based Laboratory Manual.

Table 3. Students Level of Higher-Order Thinking Ability in terms of Critical Thinking Before and After Exposure to the PBL Laboratory Manual in General Physics

Critical Thinking	Before	DI	After	DI
1. I always get inspiration and insight from the mistakes I make.	4.08	HF	4.72	VHF
2. For a controversial topic, I can always maintain clear logic to debate around different arguments.	3.48	HF	4.72	VHF
3. When others have different opinions, I usually reconsider my own opinions or conclusions.	3.64	HF	4.72	VHF
4. When confronted with a phenomenon, a set of information, or a problem situation, I usually perceive its essence very quickly	3.76	HF	4.84	VHF
5. Through analysis, I can often grasp the key points and main factors of things well, to deal with problems more efficiently.	4.16	HF	4.80	VHF
6. When others use only superficial arguments to justify their views, I usually can't accept his arguments.	3.48	HF	4.84	VHF
7. For subjective, open-ended tasks, I often consider all possibilities and assumptions as much as possible.	4.04	HF	4.84	VHF
8. I can now try not to make subjective judgments.	3.40	HF	4.72	VHF
9. I often think about right and wrong in my studies or other practices.	4.00	HF	4.76	VHF
10. I often understand other people's points of view, but I don't accept them easily.	3.72	HF	4.80	VHF
Mean	3.78	HF	4.72	VHF

The results show that students' critical thinking ability significantly improved after using the Physics Problem-Based Laboratory Manual. Their mean score rose from 3.78 (High) before the intervention to 4.72 (Very High) after, indicating

stronger skills in reasoning, evaluation, and problem-solving. This demonstrates that the manual effectively fostered higher-order thinking, aligning with findings by Abrami et al. (2015) and Savery (2015) that Problem-Based Learning enhances



critical inquiry, reflective judgment, and systematic exploration of complex problems in Physics education.

Table 4. Students Level of Higher-Order Thinking Ability in terms of Creative Thinking Before and After Exposure to the PBL Laboratory Manual in General Physics

Creative Thinking	Mean Before	DI	Mean After	DI
1. When faced with a large amount of information, I can often categorize, sort out, and reorganize it to generate new information.	3.76	HF	4.72	VHF
2. I can always concretize abstract things into clear and understandable ways of understanding such as graphics, text, etc.	3.80	HF	4.88	VHF
3. When faced with a problem situation, I can often associate it with other similar cases or relative counterexamples.	3.68	HF	4.84	VHF
4. In my studies, I can often draw on what I have learned and infer new knowledge.	3.96	HF	4.92	VHF
5. I am usually more impressed by "what I don't know" than "what I know."	4.16	HF	4.92	VHF
6. I'm usually more interested in "what could this be" than "what is this".	4.04	HF	4.80	VHF
7. I can usually predict the outcome of an event and verify that result correctly.	3.60	HF	4.96	VHF
8. When confronted with something, I can often imagine possible connections between it and other things.	3.76	HF	4.72	VHF
9. I am usually able to face challenging new things with a positive attitude.	3.76	HF	4.72	VHF
10. In my studies, I have a unique perspective of my choice and can take my own unique approach to learning activities.	3.92	HF	4.72	VHF
11. I often string together what I've learned to memorize or deepen my understanding.	4.24	VHF	4.72	VHF
12. I often solve the same problem from different angles.	3.68	HF	4.12	VHF
13. I can often think about creative inspiration immediately after I think about it	3.76	HF	4.24	VHF
Mean	3.57	HF	4.72	VHF

The results show that students' creative thinking ability significantly improved after using the Physics Problem-Based Laboratory Manual. Their mean score increased from 3.57 (High) before the intervention to 4.72 (Very High) after, reflecting stronger skills in generating ideas, exploring perspectives, and applying originality in problem-solving. This

demonstrates that the manual effectively fostered creativity in Physics learning, consistent with Barell (2010) and Newton (2014), who emphasized that Problem-Based Learning promotes innovative thinking by engaging students with open-ended, real-world problems and encouraging exploration of diverse solutions.

Table 5. Students' Level of Higher-Order Thinking Ability in terms of Decision Making Before and After Exposure to the PBL Laboratory Manual in General Physics

Decision Making	Mean Before	DI	Mean After	DI
1. When solving problems, I usually think for myself first and then ask others for advice when it is difficult to solve it.	3.80	HF	4.44	VHF
2. When faced with an important decision, I usually try to gather all the relevant information first.	4.36	VHF	4.88	VHF
3. When the problem situation changes, I can usually quickly catch the similarities and differences between it and previous experiences or experiences.	3.84	HF	4.52	VHF
4. When time is pressed, I am usually able to decide sensibly and decisively.	3.40	HF	4.48	VHF
5. I often find out after the problem is solved that my previous predictions are basically accurate.	3.88	HF	4.52	VHF
6. When there are several courses of action at the same time, I can often quickly choose the best one.	3.72	HF	4.52	VHF
7. I can often accurately and quickly extract various solutions to problems according to the requirements of the task.	3.68	HF	4.52	VHF



8. When faced with problems, because I can make objective analysis, my peers often come to me to make decisions.	3.68	HF	4.52	VHF
9. When making decisions, others often expect me to set appropriate guidelines to guide me	3.60	HF	4.56	VHF
Mean	3.77	HF	4.55	VHF

The results show that students' decision-making ability significantly improved after using the Physics Problem-Based Laboratory Manual. Their mean score rose from 3.77 (High) before the intervention to 4.55 (Very High) after, reflecting stronger skills in analyzing situations, weighing options, and making sound judgments. This indicates that the manual

effectively supported structured and reflective decision-making through real-world problem scenarios, consistent with Schmidt (2011) and Hmelo-Silver (2004), who emphasized that Problem-Based Learning fosters independent, evidence-based decisions and logical reasoning in complex contexts like Physics.

Table 6. Students' Level of Higher-Order Thinking Ability in terms of Problem-Solving Skills Before and After Exposure to the PBL Laboratory Manual in General Physics

Problem-Solving Skills	Mean Before	DI	Mean After	DI
1. I am passionate about knowledge and actively try to learn it, even if the practical value of this knowledge is not obvious.	4.00	HF	4.68	VHF
2. I often find and ask new questions or ideas from a lot of information.	3.96	HF	4.68	VHF
3. For some complex issues, I can often explain it in a few words.	3.56	HF	4.36	VHF
4. I analyze problems more through logical thinking than just by experience.	3.96	HF	4.68	VHF
5. I am often able to find evidence or reasons to explain the crux of the problem.	3.80	HF	4.28	VHF
6. I always analyze the main points of the problem before answering it.	4.16	HF	4.68	VHF
7. I am good at planning a systematic plan to solve complex problems.	3.48	HF	4.48	VHF
8. When faced with a problem, I usually think of a way to solve it boldly rather than give up.	4.00	HF	4.60	VHF
9. In the process of solving problems, I usually gather data to support my arguments through multiple channels, rather than simply copying other people's answers.	4.12	HF	4.76	VHF
10. When problems get tricky, others often expect me to keep going.	3.68	HF	4.52	VHF
11. When solving problems, I can use some appropriate strategies or tools.	4.00	HF	4.60	VHF
Mean	4.00	HF	4.68	VHF

The results show that students' problem-solving skills significantly improved after using the Physics Problem-Based Laboratory Manual. Their mean score increased from 4.00 (High) before the intervention to 4.68 (Very High) after, reflecting stronger abilities in systematic investigation, logical reasoning, and persistence in tackling complex Physics

problems. This demonstrates that the manual effectively promoted structured problem-solving through contextualized, inquiry-driven tasks, consistent with Savery (2006) and Dochy (2003), who emphasized that Problem-Based Learning enhances students' capacity to solve authentic, real-world challenges collaboratively and analytically.

Table 7. Students' Attitudes Towards General Physics Before and After Exposure to the PBL Laboratory Manual in General Physics

Items	Mean			
	Before		After	
	Mean	DI	Mean	DI
1. I like General Physics more than any other school subject.	1.56	UF	3.08	F
2. I like to do General Physics experiments.	1.88	MF	3.52	HF
3. General Physics is useful for solving everyday problems.	1.92	MF	3.60	HF
4. I am willing to spend more time reading General Physics books.	1.88	MF	2.68	F
5. General Physics lessons are interesting.	1.88	MF	3.40	HF
6. When I am working in the General Physics lab, I feel I am doing something important.	1.92	MF	3.52	HF
7. People must understand General Physics because it affects their lives.	1.88	MF	3.64	HF



8. I like trying to solve new problems in General Physics.	1.56	UF	3.64	HF
9. General Physics is one of my favorite subjects.	1.88	MF	3.32	HF
10. Doing General Physics experiments in school is fun.	1.96	MF	3.52	HF
11. General Physics is one of the most important subjects for people to study.	1.88	MF	3.56	HF
12. If I had a chance, I would do a project in General Physics.	1.56	UF	3.00	F
Overall	1.81	MF	3.37	F

The results show a positive shift in students' attitudes toward General Physics after using the Problem-Based Laboratory Manual. Their mean score increased from 1.81 (Moderately Favorable) before the intervention to 3.37 (Favorable) after, indicating greater interest, motivation, and appreciation for Physics. This suggests that the manual not only

enhanced cognitive skills but also made Physics more engaging and meaningful by integrating real-life problems and hands-on activities. Consistent with Sungur & Tekkaya (2006) and Dochy (2003), the findings affirm that Problem-Based Learning fosters more positive attitudes, autonomy, and collaboration in science education.

Table 10. Significant Difference in the Attitude of Students' Attitudes Towards General Physics Before and After Exposure to the PBL Laboratory Manual in General Physics

Group	Mean	SD	t-test	P-value	Decision at 0.05
Experimental	1.81	0.15	4.634	0.001	Reject H_0

The results show a significant improvement in students' attitudes toward General Physics after using the Problem-Based Laboratory Manual. With a probability value of 0.001 (below 0.05), the null hypothesis was rejected, confirming a statistically significant difference between pre- and post-attitudes. This indicates that the manual effectively fostered more favorable perceptions of Physics by integrating problem-based tasks that encouraged engagement and relevance. The findings support Gijbels (2005) and Savery (2006), who highlighted that Problem-Based Learning enhances motivation, interest, and positive dispositions through authentic, student-centered learning experiences.

Problems and Challenges Encountered by the Students in using the Problem-Based Laboratory Manual in General Physics

The thematic analysis revealed that students faced several challenges in using the Problem-Based Laboratory Manual in Physics. Many struggled with the problem-solving process, finding the open-ended and inquiry-driven tasks overwhelming without step-by-step guidance. Others had difficulty interpreting laboratory instructions, leading to confusion, time management issues, and frustration in self-directed learning. Additionally, the transition to a problem-based approach posed challenges for students accustomed to traditional, passive methods, as PBL required greater autonomy, persistence, and collaboration. Overall, while the manual promoted deeper engagement and higher-order thinking, students needed more scaffolding, clear guidance, and teacher support to successfully navigate the demands of problem-based learning.

Recommendation

Administrators should provide more resources, and teachers should pursue professional development to effectively implement inquiry-based learning.

Conclusion

The PBL manual is an effective tool for enhancing both cognitive and affective growth in Physics.

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