

Improving Grade 12 Students' Conceptual Understanding of Oscillations and Waves Via Peer-Led Team Learning Strategies

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Date received: May 15, 2025

Date revised: October 10, 2025

Date accepted: October 24, 2025

Originality: 90%

Grammarly Score: 99%

Similarity: 10%

Recommended citation:

Casanillo, K., Asignacion, R., Peñafiel, A., Nonan C., & Visaya, A. (2025). Improving grade 12 students' conceptual understanding of oscillations and waves via peer-led team learning strategies. *Journal of Interdisciplinary Perspectives*, 3(11), 151-157. <https://doi.org/10.69569/jip.2025.410>

Abstract. Prior research by Mitchell et al. and Wilson & Varma-Nelson consistently highlights collaborative teaching, specifically Peer-Led Team Learning, as a highly effective pedagogical strategy in various STEM disciplines. Despite its proven benefits, senior high school learners, particularly Grade 12 learners in the Philippines, frequently struggle with abstract physics concepts, as evidenced by low scores on international assessments such as PISA. This study addresses the gap in understanding how PLTL can enhance the conceptual understanding of Grade 12 STEM students in General Physics 1 within the educational context, particularly in topics related to Oscillations and Waves. The novelty lies in providing evidence of PLTL's effectiveness for this student demographic, aiming to improve scientific literacy in alignment with curriculum goals. Employing a quasi-experimental pretest-posttest two-group design, this study involved 90 Grade 12 STEM students (N=45 per group) from Bacnotan National High School in La Union, Philippines, during the 2024-2025 academic year. Conceptual understanding was measured using a researcher-made "Conceptual Understanding Test in General Physics I" focusing on Oscillations and Waves, administered both a pretest and a posttest. The experimental group received PLTL intervention, while the control group received conventional instruction. Results showed a significant improvement in conceptual understanding for the experimental group. The PLTL group's mean score was 14.74, significantly higher than the control group's mean gain of 9.62. Posttest mean scores demonstrated this improvement: the control group averaged 15.59 (SD=3.95), while the experimental group achieved 22.04 (SD=1.71), elevating their proficiency to "Moving Towards Mastery". Paired-samples t-tests confirmed significant differences between pre- and post-test scores for both groups (experimental: $t=31.09$, $p<.001$; control: $t=11.59$, $p<.001$), indicating PLTL's impact on conceptual understanding relative to traditional methods. The study confirms PLTL as an effective strategy for enhancing conceptual understanding in General Physics 1, fostering a more engaging learning environment in the Philippine setting.

Keywords: Peer-led team learning; Conceptual understanding; Collaborative, Student-centered, Peer leaders.

1.0 Introduction

Improving science education has become a global priority in preparing students for the demands of the 21st century. In the Philippines, the K to 12 science curriculum aims to cultivate scientific literacy by fostering critical thinking, problem-solving, and informed decision-making among learners (Department of Education, 2016). These competencies are essential for understanding and addressing scientific issues that affect society, the environment, and public health. However, various large-scale assessments continue to reflect significant gaps in students' scientific proficiency.

The Programme for International Student Assessment (PISA) has consistently reported low science performance among Filipino students. In the 2019 assessment, the Philippines scored an average of 357 in scientific literacy, significantly below the OECD average of 489. In 2022, the country's science score declined slightly to 355, further highlighting the persistent learning gap (OECD, 2023). These results suggest that, despite curriculum reforms, many Filipino learners continue to struggle to develop the conceptual understanding necessary for scientific competency.

Within the domain of science, physics remains one of the most conceptually challenging and least preferred subjects among students (Erinosho, 2013). Studies suggest that physics is often perceived as abstract and heavily reliant on mathematical reasoning, making it difficult for students to relate concepts to real-life experiences (Bouchée et al., 2021; Owen et al., 2008; Ogunleye, 2009). According to Angell et al. (2004), learners face challenges when they must navigate multiple representations—such as equations, graphs, and experiments—and shift between them to construct meaningful understanding. This cognitive demand is exacerbated by the cumulative nature of physics, where conceptual gaps in early topics hinder comprehension of more advanced material (Harwanto, 2019).

One particularly difficult area is Oscillations and Waves, which involves abstract principles that are not easily visualized or connected to everyday experiences. These topics require students to understand complex relationships between motion, energy, and wave behavior—concepts that are often taught through theoretical lectures and rote memorization. Traditional instructional strategies, while content-rich, may not be sufficient to promote deep conceptual understanding or sustained engagement with these topics.

At Bacnotan National High School in La Union, these challenges are especially evident. Student performance in General Physics 1—specifically in Oscillations and Waves—has reflected persistent conceptual difficulties. Classroom observations and formative assessments have indicated that learners struggle to apply concepts, shift between representations, and relate abstract ideas to physical phenomena. These issues underscore the need for more effective and student-centered instructional strategies that promote active learning and peer collaboration.

One promising pedagogical approach is Peer-Led Team Learning (PLTL), an instructional strategy designed to foster collaborative learning and improve conceptual comprehension in science and mathematics. PLTL engages students in structured, small-group workshops facilitated by trained peer leaders—students who have previously demonstrated mastery in the subject (Mitchell et al., 2012; Wilson & Varma-Nelson, 2016). The model promotes active engagement, frequent feedback, and deeper exploration of course material, while also developing leadership skills among peer facilitators (Varma-Nelson, 2017).

Research on PLTL has shown that it enhances students' conceptual understanding, problem-solving skills, and academic performance across various STEM disciplines (Mitchell et al., 2012). The approach has also been associated with increased retention and success rates among underrepresented student populations (Wilson & Arendale, 2011). Its collaborative framework not only supports cognitive development but also creates inclusive learning environments where learners actively construct meaning through peer discussion and guided inquiry.

Despite its demonstrated effectiveness, PLTL use remains limited in senior high school science instruction in the Philippines, particularly for abstract topics such as Oscillations and Waves. There is a research gap in exploring how this strategy can be adapted and implemented to enhance students' conceptual understanding in General Physics 1 at the secondary level.

Thus, this study aimed to investigate the effectiveness of Peer-Led Team Learning in improving Grade 12 students' conceptual understanding of Oscillations and Waves at Bacnotan National High School during the School Year 2024–2025. Specifically, it examined students' performance before and after the PLTL intervention, measured gains in conceptual understanding, and compared outcomes between the experimental and control groups.

2.0 Methodology

2.1 Research Design

This study utilized a quasi-experimental pretest-posttest two-group design. A two-group pretest-posttest design is an experimental design that compares changes in a dependent variable across two groups. A quasi-experimental design aims to establish a cause-and-effect relationship between an independent and a dependent variable but does not rely on random assignment. The subjects are assigned to groups based on non-random criteria (Thomas, 2020). The decision to use a quasi-experimental research design was influenced by practical considerations, including logistical constraints on classroom availability, scheduling constraints, and the students' overall educational experience. Random assignment of students to experimental conditions was not feasible due to constraints such as predetermined class sectioning and the need to maintain continuity in students' educational experiences. A quasi-experimental design offered a pragmatic solution for studying the intervention's effects while accounting for real-world constraints.

2.2 Research Locale

The study was carried out in Bacnotan, Province of La Union, Ilocos Region, Philippines. This study's research locale was Bacnotan National High School, a public secondary school in the Division of La Union. The school offers the Senior High School (SHS) program with various academic strands, including the Science, Technology, Engineering, and Mathematics (STEM) strand. Each SHS section has an average of forty-five (45) students and is supervised by subject-specialized teachers. Bacnotan is a first-class municipality located in the northern part of La Union, facing the West Philippine Sea. It is situated along the national highway, north of San Fernando City, and is known for its educational institutions and cement industry. The municipality covers approximately 65.07 square kilometers (25.12 square miles) and comprises both coastal and upland barangays. The school's proximity to the national highway and its diverse student population make it a suitable setting for instructional research.

2.3 Research Participants

A total of 90 Grade 12 STEM students enrolled in General Physics I during the first semester of School Year 2024–2025 participated in this study. The experimental group consisted of 45 students from Grade 12 STEM-Einstein, while the control group included 45 students from Grade 12 STEM-Newton. The control group received instruction through conventional lecture-based teaching, while the experimental group underwent instruction using the Peer-Led Team Learning (PLTL) approach. Participants were oriented to the research objectives and provided informed consent. A science academic head and master teacher monitored selected sessions to ensure fidelity to the curriculum and instructional strategies.

2.4 Research Instrument

The primary data collection tool was a researcher-developed Conceptual Understanding Test in General Physics I, focusing on Oscillations and Waves. The test consisted of 30 multiple-choice items aligned with the Department of Education's curriculum guide and intended learning competencies. To establish content validity, the instrument was reviewed by three subject matter experts with experience in physics instruction and assessment. Their feedback was used to revise unclear or misaligned items. The test's reliability was established through pilot testing with a group of 30 Grade 12 STEM students from a nearby school not involved in the study. The reliability coefficient, calculated using Cronbach's alpha, was 0.84, indicating high internal consistency. The same test was used for both the pretest and posttest, although the order of questions was randomized in the posttest to minimize recall bias.

2.5 Data Gathering Procedure

This study used specific steps to ensure the integrity and reliability of the results. Before the actual conduct of the study, the researchers sought approval from the school division Superintendent, the school head of Bacnotan National High School, and secured informed consent from all participants. An orientation was also conducted to explain the study's objectives. The first step in data collection involved administering the pretest to both the experimental and control groups. This initial test measures students' baseline conceptual understanding in

General Physics I, specifically in Oscillations and Waves. Second, the experimental group participated in Peer-Led Team Learning (PLTL) sessions, which included peer-led workshops and collaborative learning activities guided by trained peer leaders. At the same time, the control group continued with the conventional lecture-based instruction. After the intervention, the posttest was administered to both groups using the same test instrument. The posttest results were then collected and organized for statistical analysis to determine the effectiveness of the PLTL approach. A science master teacher and the academic track head were also present during selected sessions to observe and validate the instructional procedures and ensure curriculum alignment..

2.6 Intervention: Peer-Led Team Learning (PLTL)

The intervention in this study utilized the Peer-Led Team Learning (PLTL) approach to improve students' conceptual understanding in Physics, particularly in the topics of Oscillations and Waves. The PLTL intervention was structured in three stages:

Stage I: Peer Leaders' Training and Coaching

Before implementing the PLTL workshops, selected students were trained to become peer leaders. The researchers conducted a comprehensive coaching program inspired by Peer-Led Team Learning: A Handbook for Team Leaders by Roth, Goldstein, and Marcus (2001). The training addressed four key areas:

Content Knowledge. Peer leaders participated in advanced sessions covering the Physics concepts to be addressed in the workshop.

Pedagogical Knowledge. Training sessions included how to motivate students, engage group members, and manage team learning dynamics.

Pedagogical Content Knowledge. Specific instructional methods and strategies appropriate for Physics concepts were introduced to help peer leaders facilitate learning effectively.

Leadership Role. Peer leaders were oriented to their duties as facilitators, including managing group discussions, encouraging participation, guiding problem-solving activities, and fostering collaborative learning.

Training took place several weeks before the actual implementation. Daily feedback and coaching meetings were held after class to reinforce skills and address concerns as the workshops progressed. The training sessions were led by the teacher-researcher and observed by a master teacher in science to ensure rigor and fidelity in execution.

Stage II: Preparation of Workshop Materials

At least 3 days were allotted for preparing workshop materials for each session. These materials included:

- Guided worksheets
- Hands-on activity guides
- Concept review prompts
- Real-life application problems
- Assessment tools aligned with the session objectives

Stage III: PLTL Workshop Implementation

The workshops were held in the students' classroom from 10:00 to 11:00 AM for two weeks, with four sessions per week. Each session lasted 90 minutes and followed a structured pedagogical format:

1. Activity (Review and Motivation)
2. Analysis (Group Activity and Problem-Solving)
3. Abstraction
4. Application
5. Assessment

Workshops were facilitated entirely by trained peer leaders, while the teacher-researcher observed the implementation and documented participation and learning outcomes. An abridged version of the lesson plan used during the PLTL sessions is provided in Appendix A for reference and replicability.

2.7 Ethical Considerations

This research study followed ethical guidelines. Approval was obtained from the Division Office of La Union and the School Principal of Bacnotan National High School. All participants were provided with an orientation to the

study's objectives and procedures, and informed consent was obtained. Participation was voluntary, and students were assured of their right to withdraw at any time without academic consequences. To protect privacy, confidentiality, and anonymity, strict measures were put in place. Data were handled solely for research purposes. Peer leaders were trained not only in instructional content but also in ethical classroom conduct. Throughout the study, respect for participants' rights and academic integrity was upheld. Furthermore, to ensure this research study is free of plagiarism or research misconduct, proper communication of results must be practiced.

3.0 Results and Discussion

3.1 Proficiency Level of Grade 12 STEM Learners Conceptual Understanding in General Physics 1

Table 1 presents the results of students' Conceptual Understanding Test on the selected topics in General Physics 1 for both the control and experimental groups, comparing the pretest and posttest scores.

Table 1. Proficiency Level of Grade 12 STEM learners Conceptual Understanding in General Physics 1

Level of Proficiency	Score Range	Grading Percentile	CONTROL				EXPERIMENTAL			
			Pre-Test		Post-test		Pre-Test		Post-test	
			N	%	N	%	N	%	N	%
Mastered	24-25	96-100	0		0				7	16
Closely Approximating Mastery	22-23	86-95	0		11	25	0		22	49
Moving Towards Mastery	17-21	66-85	1	2	17	38	0		14	31
Average Mastery	9-16	35-65	17	38	15	33	12	27	2	4
Low Mastery	4-8	15-34	25	56	2	4	28	62	0	
Very Low Mastery	1-3	5-14	2	4	0		3	7	0	
Absolutely No Mastery	0	0-14	0		0		2	4	0	
		TOTAL:	45	100	45	100	45	100	45	100
Mean $\pm$			7.82 $\pm$ 2.96		15.59 $\pm$ 3.95		6.93 $\pm$ 2.47		22.04 $\pm$ 1.71	
Proficiency Level			Low Mastery		Average Mastery		Low Mastery		Closely Approximating Mastery	

The pretest mean score for the control group was 7.82 (SD = 2.96), while the experimental group had a mean score of 6.93 (SD = 2.47). Both groups were categorized as having "Low Mastery," indicating that most students demonstrated a limited conceptual understanding of the subject matter. This suggests that the groups had comparable performance levels at the start of the experiment, relying solely on their prior knowledge of General Physics 1 to answer the pretest, as no formal instruction on the selected topics had yet occurred. High school students often struggle to understand the principles of oscillations and waves, which is attributed to misconceptions and inadequate problem-solving skills (Amrullah & Busyiri, 2024; Rachmawati et al., 2024). Effective pedagogical strategies, such as the multiple representation approach, have shown promise in improving understanding (Kriek & Legesse, 2023).

A notable improvement was observed in the posttest results. The control group achieved a mean posttest score of 15.59 (SD = 3.95), while the experimental group attained a mean score of 22.04 (SD = 1.71). This elevated the experimental group's proficiency level to "Moving Towards Mastery." These results underscore the positive impact of Peer-Led Team Learning (PLTL) strategies on students' conceptual understanding in Physics 1. The findings align with prior research, such as Hockings et al. (2008), as cited in Brush (2024), which revealed that students participating in PLTL groups performed approximately one-third of a grade point higher in General Chemistry courses than those who did not participate.

The study also revealed a significant difference in the mean gain in conceptual understanding between the control and experimental groups. The control group exhibited a mean gain of 9.62, while the experimental group achieved a mean gain of 14.74. The greater mean gain in the experimental group suggests that PLTL fosters more substantial conceptual improvement compared to traditional teaching methods. This is likely due to the collaborative, student-centered nature of PLTL, which emphasizes peer interaction, problem-solving, and active engagement with course materials, thereby facilitating a deeper understanding of scientific concepts. These findings are consistent with Snyder and Sloane's (2015) study, which found that PLTL enhanced performance and engagement in science by encouraging peer-led interactions, open discussions, and problem-solving activities.

3.2 Comparative Analysis of Pre-test and Post-test Scores of the Respondents

Significant Difference under Peer-Led Team Learning (PLTL)

Table 2 shows the results of the paired samples t-test conducted to determine whether there is a significant difference between the means of pretest and posttest scores of students under PLTL.

Table 2. *Comparative Analysis of Pre-test and Posttest Scores of the Respondents*

Phase of Study	Mean	SD	N	t	df	p (1-tailed)
Pretest	6.93	2.47	45	31.09	44	<.001
Posttest	22.04	1.71	45			

*p<.05

As shown in the table, the mean pretest score is 6.93 with a standard deviation of 2.47, while the mean posttest score is 21.67 with a standard deviation of 2.30. The analysis revealed a significant difference between the pretest and posttest scores, with a t-value of 31.09 and a p-value of < .001. This indicates that PLTL is effective in improving Grade 12 learners' conceptual understanding of the selected topics in General Physics. The findings are consistent with those of Lamina et al. (2020), which revealed significant differences in the mean chemistry achievement and engagement scores before and after exposure to PLTL. Lamina et al. (2020) concluded that PLTL is a beneficial teaching-learning strategy for enhancing students' science learning.

Significant Difference under Conventional Instruction (CI)

Table 3 presents the results of the paired samples t-test comparing the mean pretest and posttest scores of students under Conventional Instruction (CI).

Table 3. *Significant Difference between the Pre-test and Posttest Scores of Conventional Instruction Group on Concept Test*

Phase of Study	Mean	SD	N	t	df	p (1-tailed)
Pretest	7.82	2.96	45	11.59	44	<.001
Posttest	16.04	3.95	45			

*p<.05

The difference between the two assessments is statistically significant, with a t-value of 11.59 and a p-value less than 0.001. Despite this, the mean pretest score of 7.82 is classified as "Low Mastery," while the mean posttest score of 16.04 is classified as "Average Mastery." The significant gain in scores suggests that the conventional method facilitated learning to some extent and that the learning objectives for the control group were partially achieved. However, the comparison also highlights that students in the Peer-Led Team Learning (PLTL) group performed considerably better, particularly in the posttest. This implies that PLTL was more effective in enhancing conceptual understanding, even among students with varied levels of prior knowledge and motivation.

These results align with existing literature on PLTL's effectiveness in science education. According to Wilson and Varma-Nelson (2016) and Frey et al. (2018), PLTL improves long-term retention, fosters deeper conceptual understanding, and supports academic success. The present study's experimental group exhibited a notable mean difference of 14.74 between pretest and posttest scores—echoing the findings of Snyder et al. (2016) and Wells (2014), who reported similar benefits of peer-led strategies in chemistry and biology education. Furthermore, the success of PLTL among students with initially lower mastery contributes to growing evidence of its applicability for marginalized or underperforming learners, as discussed by Hickman (2016) and Okeya (2022). This research affirms the relevance of PLTL in bridging achievement gaps and improving equity in science education.

Thus, this study not only reinforces prior research but also extends the body of evidence to a new context—that of Filipino Grade 12 STEM students—where science performance has historically lagged, as reflected in national assessments and PISA results. In support of these quantitative findings, qualitative data from student interviews further demonstrated improved conceptual understanding and increased engagement. Many participants attributed their improved comprehension in General Physics 1 to the PLTL sessions. Learner 5 noted, "It is more fun and more engaging because we can relate with our leader and cope with the lesson easily." This statement reflects a deeper connection to the learning material and suggests that the peer-led format fostered a more accessible and motivating learning environment.

Classroom observations conducted during the PLTL implementation reinforced these findings. Students in the experimental group showed greater engagement, collaboration, and confidence than those in the control group.

The teacher-observer remarked, “During your PLTL sessions on oscillations and waves, I observed that students were eager to solve problems together, clarify misconceptions among peers, and explain their reasoning confidently in front of the group.” This observation underscores the development of a more student-centered, interactive learning environment, a core strength of the PLTL model. The visible increase in peer discussion, problem-solving dialogue, and willingness to participate reflects a deeper conceptual engagement with the content. It supports the quantitative gains found in the posttest scores.

Overall, while conventional instruction can meet learning objectives, PLTL demonstrates a significantly greater impact on student performance. Its collaborative, interactive nature likely accounts for the observed improvements in conceptual understanding. These results highlight the potential of PLTL as a scalable and effective strategy for advancing science education outcomes, particularly in contexts with diverse learner needs.

4.0 Conclusion

The study aimed to investigate the effectiveness of Peer-Led Team Learning in enhancing Grade 12 students' conceptual understanding of Oscillations and Waves at Bacnotan National High School. Specifically, it examined student performance before and after the PLTL intervention, measured gains in conceptual understanding, and compared outcomes between the experimental and control groups. The findings overwhelmingly supported PLTL as an effective strategy for improving the conceptual understanding of Grade 12 STEM learners in General Physics 1. A significant difference in mean gain between the experimental and control groups highlighted the positive impact of PLTL on student learning outcomes, indicating that PLTL is significantly more effective than conventional instruction in fostering conceptual understanding. The collaborative and interactive nature of PLTL likely contributed to its greater impact, even among students with diverse prior knowledge and motivation levels. For future related work, further research could explore the long-term retention of concepts learned through PLTL and investigate its adaptability across other challenging science topics beyond physics, building on its effectiveness. Additionally, exploring the specific mechanisms through which PLTL fosters deeper conceptual understanding and how it can be optimally integrated into diverse educational contexts would be valuable.

5.0 Contributions of Authors

All authors contributed equally to the development of each section of the manuscript. They have jointly reviewed and approved the final version for publication.

6.0 Funding

This research did not receive any specific grant from funding agencies in the public or commercial sectors.

7.0 Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

8.0 Acknowledgment

The researchers humbly acknowledge the guidance and grace of Almighty God, whose wisdom and strength made the completion of this study possible. Special thanks to the researchers' families and friends for their unconditional love and prayers. Deepest gratitude is also extended to Ma'am Avelina Visaya for her invaluable insights, constructive feedback, and unwavering support. Her expertise has greatly contributed to the enhancement and refinement of this study in countless ways.

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