Mobile-Assisted Experimentation Using the Phyphox Application: Effects on Grade 8 Students' Conceptual Understanding of Pendulum Motion

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ABSTRACT

This study investigated the effectiveness of mobile-assisted experimentation using the Physical Phone Experiments (Phyphox) application in enhancing Grade 8 students' conceptual understanding of pendulum motion. A quantitative quasi-experimental pretest–posttest design was employed involving 90 Grade 8 students assigned to three instructional conditions: traditional instruction, Phyphox-assisted experimentation with teacher assistance, and teacherless Phyphox-assisted experimentation. Data were collected using a researcher-developed 40-item two-tier conceptual understanding test with a Kuder–Richardson Formula 20 (KR-20) reliability coefficient of 0.934. Results of the Wilcoxon Signed-Rank Test revealed significant improvements in conceptual understanding across all groups: traditional instruction ($Z = -4.102$, $p < .001$), Phyphox-assisted experimentation with teacher assistance ($Z = -4.788$, $p < .001$), and teacherless Phyphox-assisted experimentation ($Z = -4.430$, $p < .001$). The Kruskal–Wallis H Test indicated no significant difference among the groups in the pretest scores ($\chi^2 = 0.157$, $p = .925$) but revealed a significant difference in the posttest scores ($\chi^2 = 5.189$, $p = .045$). Post hoc analysis using the Mann–Whitney U Test showed that the Phyphox-assisted experimentation with teacher assistance group significantly outperformed the traditional instruction group ($U = 306.500$, $Z = -2.134$, $p = .033$). In contrast, no significant differences were observed between the traditional and teacherless Phyphox groups ($p = .075$) or between the two Phyphox-assisted groups ($p = .847$). The Phyphox-assisted experimentation with the teacher assistance group obtained the highest posttest mean score ($M = 89.90$, $SD = 3.10$). The findings suggest that mobile-assisted experimentation represents a promising instructional approach for enhancing students' conceptual understanding of pendulum motion and that teacher facilitation may contribute to improved learning outcomes. However, the results should be interpreted within the limitations of a quasi-experimental design conducted in a single public secondary school. The study provides empirical support for integrating smartphone sensor-based experimentation into physics instruction, particularly in resource-constrained educational contexts.

Keywords: Conceptual Understanding, Mobile-Assisted Learning, Pendulum Motion, Phyphox Application, Physics Education, Smartphone Sensor Experimentation

INTRODUCTION

Science education plays a vital role in developing learners' scientific literacy, critical thinking, and problem-solving skills. In physics education, however, students frequently encounter difficulties in understanding concepts that are abstract, mathematically represented, and often disconnected from everyday experiences. One such concept is pendulum motion, a foundational topic in junior high school physics that serves as an entry point to periodic motion and simple harmonic motion (Ling et al., 2016). Understanding pendulum motion requires learners to explain relationships among variables such as length, period, and energy, yet many students continue to exhibit misconceptions and a fragmented understanding of these concepts (Wangchuk et al., 2023).

Previous studies have reported low levels of conceptual understanding of simple harmonic motion among learners. Tumanggor et al. (2020) found that only 36.4% of students demonstrated complete understanding of oscillatory motion concepts, while many held misconceptions regarding the relationship between pendulum length and period. Similar findings were reported by Mufit et al. (2024) and Wardani (2020), who observed that only a limited proportion of students achieved sound conceptual understanding of motion-related concepts. These difficulties are often reinforced by formula-based instruction, which encourages memorization rather than conceptual reasoning and meaningful understanding (Ballesta-Claver et al., 2021). Consequently, pendulum motion provides a suitable context for investigating students' conceptual understanding because it requires learners to explain physical relationships rather than recall formulas (Monteiro & Martí, 2022).

The implementation of the MATATAG Curriculum emphasizes inquiry-based and learner-centered approaches to science instruction. However, many Philippine public secondary schools continue to experience laboratory shortages and limited access to scientific equipment. Ocenar and Mendaño (2026) reported that thousands of public high schools nationwide still lack adequate laboratory facilities, restricting opportunities for hands-on experimentation and often reinforcing teacher-centered instruction. Such limitations may hinder the development of conceptual understanding and scientific reasoning skills, particularly in physics, where learners benefit from observation, experimentation, and evidence-based explanations.

Recent advances in educational technology have provided alternative approaches to science instruction. Mobile-assisted learning technologies, particularly smartphone-based applications, have emerged as practical and cost-effective tools for supporting inquiry-based learning. Research has demonstrated that mobile technologies can improve student engagement, conceptual understanding, and scientific inquiry skills (Crompton & Burke, 2018; Darling-Hammond et al., 2020; Mayer, 2020). One such innovation is the Physical Phone Experiments (Phyphox) application, which transforms smartphones into scientific instruments that collect and display real-time experimental data via built-in sensors (Klein et al., 2019; Hochberg et al., 2020). By enabling learners to observe and analyze physical phenomena directly, smartphone-assisted experimentation provides opportunities for more meaningful and data-driven learning experiences.

Studies have shown that smartphone-assisted experiments can enhance students' conceptual understanding and engagement in science learning. Zhao (2025) and Rediansyah (2022) reported that learners who participated in smartphone-based experiments demonstrated improved conceptual understanding compared to those exposed to conventional instruction. Similarly, Pacala and Mendaño (2025) emphasized the potential of combining smartphone sensors and simulations to broaden access to physics laboratory experiences, particularly in resource-constrained settings. In the Philippine context, Mateo (2023) found that Phyphox-based experiments yielded results comparable to those of traditional laboratory equipment and were feasible to implement in schools with limited resources.

Despite these promising findings, empirical evidence regarding the effectiveness of smartphone sensor-assisted experimentation in Philippine secondary school physics classrooms remains limited. Existing local studies have focused primarily on ICT readiness, digital literacy, and perceptions toward technology integration rather than measurable gains in conceptual understanding (Pacala & Pacala, 2025). Furthermore, literature reviews have highlighted the scarcity of context-specific studies examining the effects of mobile-assisted experimentation on students' conceptual understanding in resource-constrained educational environments (Anselmo et al., 2024). Addressing this gap is important to determine whether mobile-assisted experimentation can serve as an effective instructional strategy for improving physics learning outcomes.

Moreover, while technology provides opportunities for independent exploration and inquiry, effective science learning continues to depend on guided reasoning, conceptual clarification, and meaningful engagement. Teacher support may play a critical role in helping students interpret experimental data, connect evidence to scientific concepts, and address misconceptions. Consequently, it is important to examine whether differences exist in conceptual understanding when mobile-assisted experimentation is implemented with varying levels of instructional support.

Therefore, this study investigated the effectiveness of three instructional approaches for teaching pendulum motion to Grade 8 students: traditional instruction, teacher-assisted Phyphox-assisted experimentation, and teacherless Phyphox-assisted experimentation. Specifically, the study sought to determine the pretest and posttest performance of students under the three instructional conditions, examine differences within and among groups, and evaluate the effectiveness of mobile-assisted experimentation in improving students' conceptual understanding of pendulum motion. The findings may provide empirical evidence for integrating low-cost, technology-enhanced instructional strategies in physics education, particularly in schools with limited laboratory resources.

METHODS

Research Design

This study employed a quantitative quasi-experimental pretest–posttest design to determine the effectiveness of mobile-assisted experimentation using the Phyphox (Physical Phone Experiments) application in enhancing Grade 8 students' conceptual understanding of pendulum motion. Three instructional conditions were compared: (1) traditional instruction, (2) Phyphox-assisted experimentation with teacher assistance, and (3) teacherless Phyphox-assisted experimentation. A quasi-experimental approach was adopted because random assignment of individual students was not feasible; thus, intact classes were utilized and assigned to treatment conditions through a lot-drawing procedure. Pretest and posttest assessments were administered to determine changes in conceptual understanding following the intervention.

Research Locale and Participants

The study was conducted in a public secondary school under the Schools Division of Catbalogan City, Philippines, during School Year 2025–2026. The school implements the MATATAG K–10 Curriculum and represents a typical public school setting, characterized by diverse students' academic abilities and limited laboratory resources.

The participants consisted of 90 Grade 8 students distributed across three intact science classes. Through a lot-drawing procedure, each class was assigned to one of three instructional conditions: traditional instruction (n = 30), Phyphox-assisted experimentation with teacher assistance (n = 30), and teacherless Phyphox-assisted experimentation (n = 30). Students who completed both the pretest and posttest and participated throughout the intervention period were included in the study.

Research Instrument

Data were gathered using a researcher-developed 40-item two-tier multiple-choice test designed to measure students' conceptual understanding of pendulum motion. The instrument was administered as both a pretest and a posttest. Each item consisted of two components: the first tier assessed conceptual knowledge, while the second tier examined students' reasoning for their responses.

The instrument covered key concepts in pendulum motion, including the relationship between pendulum length and period, the role of gravity, the effect of amplitude under the small-angle approximation, and energy transformations during oscillation. A scoring scheme ranging from 0 to 3 points per item was utilized to evaluate both answer accuracy and conceptual reasoning.

Validation and Reliability of Instrument

The researcher developed a two-tier conceptual understanding test that initially consisted of 50 items and underwent content validation by three science education specialists and one physics education expert. The validators evaluated the instrument for content relevance, clarity, alignment with the intended learning competencies, and suitability for Grade 8 learners. Revisions were incorporated based on the validators' recommendations before pilot testing.

The revised instrument was subsequently pilot-tested among 30 Grade 8 students from a public secondary school outside the study site. Item analysis was performed using difficulty and discrimination indices to assess item quality. Items exhibiting extreme difficulty levels or inadequate discriminatory power were revised or eliminated, resulting in a final 40-item instrument.

Internal consistency reliability was assessed using the Kuder–Richardson Formula 20 (KR-20), yielding a coefficient of 0.934, indicating excellent reliability. The instrument was therefore deemed appropriate for measuring students' conceptual understanding of pendulum motion.

Data Gathering Procedure

Before data collection, ethical clearance was secured from the Institutional Human Ethics Review Committee, and permission to conduct the study was obtained from the school administration. Informed consent from parents or guardians and assent from student participants were likewise obtained before the study's implementation.

The study commenced with a pretest administered to all participants to assess their baseline conceptual understanding of pendulum motion. Following the pretest, the three intact Grade 8 classes were exposed to their respective instructional conditions over a fifteen-day intervention period from July 21 to August 8, 2025.

The Traditional Instruction Group received teacher-centered instruction, including lecture-discussion, textbook-based explanations, demonstrations, and guided seatwork activities, consistent with the prescribed Grade 8 science curriculum. The Phyphox-Assisted Experimentation with Teacher Assistance Group engaged in smartphone sensor-based pendulum experiments using the Phyphox application. Throughout the activities, the teacher provided instructional scaffolding through conceptual questioning, guidance in setting up experiments, facilitation of data interpretation, clarification of misconceptions, and assistance in relating experimental observations to scientific principles of pendulum motion. The Teacherless Phyphox-Assisted Experimentation Group performed the same Phyphox-based experiments using structured activity guides and written instructions but received minimal teacher intervention during data collection, analysis, and interpretation. Students independently conducted the experiments and derived conclusions from the generated data.

Upon completion of the intervention, all participants completed the posttest using the same conceptual understanding instrument. The resulting pretest and posttest scores were subsequently analyzed to determine the effectiveness of the three instructional approaches in enhancing students' conceptual understanding of pendulum motion.

Statistical Treatment of Data

Data were analyzed using descriptive and inferential statistical techniques. Frequency, percentage, mean, and standard deviation were computed to describe the pretest and posttest performance of students under the three instructional conditions.

Given the distributional characteristics of the data, nonparametric statistical procedures were employed. The Wilcoxon Signed-Rank Test was used to determine significant differences between the pretest and posttest scores within each instructional group. The Kruskal–Wallis H Test was used to examine significant differences among the three instructional groups in pretest and posttest performance. When significant differences were detected, post hoc pairwise comparisons were conducted using the Mann–Whitney U Test to identify specific group differences.

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS). Hypotheses were tested at the 0.05 level of significance. Decisions regarding the acceptance or rejection of the null hypotheses were based on the corresponding p-values, with $p \leq .05$ indicating statistical significance.

Ethical Considerations

The study was approved by the Institutional Human Ethics Review Committee *(IHREC Code: 2026-0010-G).* Ethical principles of voluntary participation, informed consent, confidentiality, anonymity, and data privacy were strictly observed throughout the research. Participants were informed of their right to withdraw at any time without penalty. To protect participants' identities, coded identifiers were used in place of personal information. All collected data were stored securely and used solely for research purposes. Safety measures were likewise observed during the pendulum experiments conducted using the Phyphox application.

RESULTS AND DISCUSSION

Pretest Performance of Students Exposed to the Three Instructional Conditions

Table 1 presents the distribution of pretest scores for students exposed to traditional instruction, Phyphox-assisted experimentation with teacher assistance, and teacherless Phyphox-assisted experimentation before the implementation of the instructional interventions.

Table 1. Pretest Scores of Students Exposed to the Three Instructional Conditions

Percentage Score	Traditional		Phyphox w/ Teacher		Phyphox w/o Teacher	
	No. of Students	%	No. of Students	%	No. of Students	%
90–100 (O)	1	3.30	–	–	–	–
85–89 (VS)	11	36.70	8	26.70	10	33.30
80–84 (S)	10	33.30	13	43.30	14	46.70
75–79 (FS)	2	6.70	7	23.30	3	10.00
<75 (DNME)	6	20.00	2	6.70	3	10.00
Total	30	100.00	30	100.00	30	100.00
Mean	81.43		81.67		81.83	
SD	6.13		4.20		5.02	

Legend: 90–100 = Outstanding (O); 85–89 = Very Satisfactory (VS); 80–84 = Satisfactory (S); 75–79 = Fairly Satisfactory (FS); ≤75 = Did Not Meet Expectations (DNME).

The traditional instruction group obtained a mean pretest score of 81.43 (SD = 6.13), while the Phyphox with teacher assistance and teacherless Phyphox groups obtained mean scores of 81.67 (SD = 4.20) and 81.83 (SD = 5.02), respectively. Based on the Department of Education (DepEd) adjectival rating scale, all three groups achieved a Satisfactory level of performance.

The similarity of the mean scores indicates that the three groups had comparable baseline conceptual understanding of pendulum motion before the implementation of the instructional interventions. Establishing equivalent baseline performance is important in quasi-experimental studies because it strengthens the validity of subsequent comparisons and minimizes the influence of pre-existing differences among groups.

The findings suggest that although students demonstrated a basic understanding of pendulum motion concepts, their conceptual mastery remained incomplete. This observation supports the constructivist perspective that learners enter instructional settings with prior knowledge that serves as the foundation for new learning experiences. According to Bruner (2019), meaningful learning occurs when learners actively connect new information with existing cognitive structures.

Furthermore, the satisfactory pretest performance indicates that students possessed initial knowledge of pendulum motion but still required deeper conceptual development. This finding is consistent with Aying and Mendaño (2024), who reported that learners often demonstrate a partial understanding of motion concepts while still holding misconceptions about the relationships among pendulum length, period, and gravitational effects. Similarly, Monteiro and Martí (2022) observed that students frequently experience difficulties in developing conceptual mastery of oscillatory motion due to the abstract nature of the concepts and the predominance of formula-based instruction.

Overall, the comparable pretest performance of the three groups provided a suitable foundation for evaluating the effectiveness of traditional instruction, teacher-assisted Phyphox-assisted experimentation, and teacherless Phyphox-assisted experimentation in improving students’ conceptual understanding of pendulum motion.

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Posttest Performance of Students Exposed to the Three Instructional Conditions

Table 2 presents the distribution of posttest scores of students exposed to traditional instruction, Phyphox-assisted experimentation with teacher assistance, and teacherless Phyphox-assisted experimentation following the implementation of the instructional interventions.

Table 2. Posttest Scores of the Three Groups of Respondents

Percentage Score	Traditional		Phyphox w/ Teacher		Phyphox w/o Teacher	
	No. of Students	%	No. of Students	%	No. of Students	%
90–100 (O)	10	33.3	17	56.7	14	46.7
85–89 (VS)	16	53.3	11	36.7	11	36.7
80–84 (S)	3	10.0	2	6.7	3	10.0
75–79 (FS)	1	3.3	–	–	2	6.7
<75 (DNME)	–	–	–	–	–	–
Total	**30**	**100.00**	**30**	**100.00**	**30**	**100.00**
Mean	**87.96 (VS)**		**89.90 (O)**		**89.47 (VS)**	
SD	**3.57**		**3.10**		**5.26**	

Legend: 90–100 = Outstanding (O); 85–89 = Very Satisfactory (VS); 80–84 = Satisfactory (S); 75–79 = Fairly Satisfactory (FS); ≤75 = Did Not Meet Expectations (DNME).

The results revealed notable improvements in the performance of all three groups following the instructional interventions. In the traditional instruction group, the majority of students (53.3%) achieved scores within the Very Satisfactory range, while 33.3% attained Outstanding performance. In contrast, the Phyphox group with teacher assistance recorded the highest proportion of students in the Outstanding category (56.7%), followed by the teacherless Phyphox group at 46.7%. Notably, no student in any group scored below 75, indicating that all participants met the minimum expected learning outcomes after the intervention.

In terms of mean performance, the Phyphox with teacher assistance group obtained the highest posttest mean score (M = 89.90, SD = 3.10), corresponding to an Outstanding level of achievement. This was followed by the teacherless Phyphox group (M = 89.47, SD = 5.26) and the traditional instruction group (M = 87.96, SD = 3.57), both of which were interpreted as Very Satisfactory. These findings suggest that although all instructional approaches contributed to learning gains, students exposed to mobile-assisted experimentation demonstrated higher levels of conceptual understanding than those who received traditional instruction alone.

The superior performance of the Phyphox-assisted groups supports the growing body of evidence highlighting the effectiveness of mobile-assisted experimentation in physics education. Through smartphone sensors and real-time data visualization, learners can directly observe relationships among physical variables and connect theoretical concepts to observable phenomena. Such experiences promote active engagement, inquiry, and evidence-based reasoning, which are essential components of meaningful conceptual learning.

The findings are consistent with Christonasi and Kotsis (2026), who reported that smartphone-assisted experiments significantly improved students' conceptual understanding of motion concepts by enabling learners to collect, analyze, and interpret real-time experimental data. Similarly, Momox and Ortega De Mayo (2020) emphasized that mobile sensor technologies help students visualize abstract physics concepts and bridge the gap between mathematical representations and physical phenomena. Leelamma and Indira (2017) likewise found that mobile-assisted inquiry learning environments significantly enhance students' knowledge acquisition, comprehension, and application of scientific concepts compared with conventional instructional approaches.

Furthermore, the higher mean score obtained by the Phyphox with teacher assistance group suggests that teacher facilitation remains an important component of technology-enhanced learning. While mobile technologies provide opportunities for independent exploration, teacher guidance helps learners interpret data, address misconceptions, and construct scientifically accurate explanations. This finding aligns with constructivist perspectives that emphasize the role of guided inquiry and scaffolding in promoting deeper conceptual understanding.

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Overall, the posttest results demonstrate that all instructional approaches contributed positively to students' conceptual understanding of pendulum motion. However, Phyphox-assisted experimentation, particularly when combined with teacher guidance, produced the highest level of achievement, indicating its potential as an effective and scalable instructional strategy for physics education in resource-constrained learning environments.

Comparison Between Pretest and Posttest Scores Within Each Instructional Group

Table 3 presents the results of the Wilcoxon Signed-Rank Test used to determine whether significant differences existed between the pretest and posttest scores of students exposed to traditional instruction, Phyphox-assisted experimentation with teacher assistance, and teacherless Phyphox-assisted experimentation.

Table 3 Comparison Between Pretest- Posttest Mean Scores Within Each of the Three Groups of Respondents

Ranks					Test Statistics		
		N	Mean Rank	Sum of Ranks	*Z*	p-value	Evaluation
Pretest-Posttest (Traditional)	Negative Ranks	24[a]	14.98	359.50	-4.102[b]	.000	Significant
	Positive Ranks	3[b]	6.17	18.50			
	Ties	3[c]	-	-			
	Total	30					
Pretest-Posttest (Phyphoxs with Teacher)	Negative Ranks	30[d]	15.50	465.00	-4.788[b]	.000	Significant
	Positive Ranks	0[e]	0.00	0.00			
	Ties	0[f]	-	-			
	Total	30					
Pretest-Posttest (Phyphoxs with No Teacher)	Negative Ranks	27[g]	15.63	422.00	-4.430[b]	.000	Significant
	Positive Ranks	2[h]	6.50	13.00			
	Ties	1[i]	-	-			
	Total	30					
a. T_Pre < T_Post					b. Based on positive ranks.		
b. T_Pre > T_Post							
c. T_Pre = T_Post							
d. PwT_Pre < PwT_Post							
e. PwT_Pre > PwT_Post							
f. PwT_Pre = PwT_Post							
g. PwoT_Pre < PwoT_Post							
h. PwoT_Pre > PwoT_Post							
i. PwoT_Pre = PwoT_Post							

The results revealed significant differences between the pretest and posttest scores across all instructional groups. The traditional instruction group obtained a computed Z value of −4.102 ($p < .001$), indicating a significant improvement in students' conceptual understanding following the intervention. Likewise, the Phyphox with teacher-assistance group demonstrated a significant increase in performance, as evidenced by a Z-value of −4.788 ($p < .001$). Similarly, the teacherless Phyphox group recorded a significant improvement with a computed Z value of −4.430 ($p < .001$).

The predominance of negative ranks across all groups indicates that posttest scores were generally higher than pretest scores, demonstrating positive learning gains following the instructional interventions. Notably, the Phyphox with teacher assistance group exhibited 30 negative ranks and no positive ranks, indicating that all students either improved or maintained their performance after the intervention. This finding suggests that integrating mobile-assisted experimentation with teacher guidance yielded the most consistent improvement among the three instructional conditions.

The significant improvement observed in all groups indicates that each instructional approach contributed positively to students' conceptual understanding of pendulum motion. However, the stronger and more consistent gains observed in the Phyphox-assisted groups suggest that mobile-assisted experimentation may provide additional opportunities for conceptual development beyond those offered by conventional instruction. Through direct interaction with real-time experimental data, students observed relationships among physical variables and constructed evidence-based explanations of pendulum behavior.

These findings support previous studies demonstrating the effectiveness of mobile-assisted inquiry learning in science education. Liu et al. (2021) reported that mobile-supported inquiry-based learning significantly enhanced students' engagement and conceptual reasoning by promoting active participation in scientific investigations. Similarly, Nikou and Economides (2018) found that mobile-assisted learning environments facilitate deeper conceptual understanding by enabling learners to collect data, test hypotheses, and engage directly in inquiry processes.

Overall, the findings indicate that while traditional instruction remains effective in improving conceptual understanding, mobile-assisted experimentation, particularly when supported by teacher guidance, provides a more conducive learning environment for developing a deeper understanding of pendulum motion concepts. The results further highlight the importance of combining technological tools with instructional scaffolding to maximize learning outcomes in physics education.

Comparison of Pretest and Posttest Scores Among the Three Instructional Groups

Table 4 presents the results of the Kruskal–Wallis H Test used to determine whether significant differences existed among the pretest and posttest scores of students exposed to traditional instruction, Phyphox-assisted experimentation with teacher assistance, and teacherless Phyphox-assisted experimentation.

Table 4 Comparison of the Pretests and Posttests Means Scores Among the Three Groups of Student-Respondents

	Methods	Mean Rank	χ^2-value	P-value	Evaluation
Pretest Scores	Traditional	46.67	0.157	0.925	Not Significant
	Phyphox with Teacher	44.05			
	Phyphox with No Teacher	45.78			
Posttest Scores	Traditional	36.72	5.189	0.045	Significant
	Phyphox with Teacher	50.72			
	Phyphox with No Teacher	49.07			

Significant at $p<0.05$; 2-tailed; df:2

The results revealed no significant difference in pretest scores among the three instructional groups ($\chi^2 = 0.157$, $p = 0.925$). The traditional instruction group obtained a mean rank of 46.67, the Phyphox with teacher assistance group obtained a mean rank of 44.05, and the teacherless Phyphox group obtained a mean rank of 45.78. Since the computed p-value exceeded the 0.05 significance level, the null hypothesis was retained. This finding indicates that the three groups possessed comparable levels of conceptual understanding of pendulum motion before the implementation of the instructional interventions. The absence of significant differences in baseline performance strengthens the study's internal validity. It supports the assumption that any subsequent differences in learning outcomes are attributable to the instructional treatments rather than to pre-existing disparities among participants.

In contrast, a significant difference was observed among the posttest scores of the three groups ($\chi^2 = 5.189$, $p = 0.045$). The Phyphox with teacher assistance group obtained the highest mean rank (50.72), followed by the teacherless Phyphox group (49.07), while the traditional instruction group recorded the lowest mean rank (36.72). The significant posttest result indicates that the instructional approaches differed in their effectiveness in enhancing students' conceptual understanding of pendulum motion.

The higher mean ranks obtained by the Phyphox-assisted groups suggest that mobile-assisted experimentation provided students with more effective learning experiences than traditional instruction alone. By enabling learners to collect, visualize, and analyze real-time experimental data, the Phyphox application facilitated active engagement with scientific concepts and promoted evidence-based reasoning. These experiences may have contributed to a deeper understanding of the relationships among pendulum variables, including length, period, and gravitational effects.

The findings support previous studies emphasizing the value of smartphone-assisted experimentation in physics education. Uy et al (2026) reported that smartphone sensor-based experiments significantly improve students' conceptual understanding by allowing them to observe and investigate physical phenomena directly. Similarly, Zhao (2025) found that mobile-assisted inquiry learning enhances students' scientific reasoning and conceptual comprehension through active exploration and real-time data analysis. The findings also align with constructivist learning theory, which posits that knowledge is constructed through active engagement with experiences and meaningful interaction with learning environments.

Overall, the results indicate that although the three groups started with comparable levels of conceptual understanding, significant differences emerged after the interventions. The higher posttest rankings of the Phyphox-assisted groups, particularly the group that received teacher guidance, suggest that mobile-assisted experimentation can be an effective instructional strategy for improving Grade 8 learners' conceptual understanding of pendulum motion.

Pairwise Comparison of Posttest Scores Among the Three Instructional Groups

Table 5 presents the results of the Mann–Whitney U test conducted as a post hoc analysis following the significant Kruskal–Wallis H test result. The analysis was performed to identify which specific instructional groups differed significantly in terms of posttest performance.

The results revealed a significant difference between the traditional instruction group and the Phyphox with teacher assistance group (U = 306.500, Z = -2.134, p = .033). The Phyphox-with-teacher-assistance group obtained a higher mean rank (35.28) than the traditional instruction group (25.72), indicating superior posttest performance among students who engaged in mobile-assisted experimentation with teacher guidance. This finding suggests that integrating smartphone-based experimentation, coupled with instructional support, enhanced students' conceptual understanding of pendulum motion more effectively than traditional instruction alone.

Table 5 Post Hoc Analysis of the Comparison of the Posttest Means Scores of the Three Groups of Student-Respondents

Pairwise Comparison		Mean Rank	Sum of Ranks	U-test	Z	p-Value	Evaluation
Pair 1	Traditional	25.72	771.50	306.500	-2.134	.033	Significant
	Phyphox with Teacher	35.28	1058.50				
Pair 2	Traditional	26.50	795.00	330.000	-1.782	.075	Not Significant
	Phyphox without Teacher	34.50	1035.00				
Pair 3	Phyphox with Teacher	30.93	928.00	437.000	-.193	.847	Not Significant
	Phyphox without Teacher	30.07	902.00				

Significant at p<0.05; 2-tailed

In contrast, no significant difference was observed between the traditional instruction group and the teacherless Phyphox group (U = 330.000, Z = -1.782, p = .075), although the teacherless Phyphox group obtained a relatively higher mean rank (34.50) than the traditional group (26.50). Similarly, the comparison between the Phyphox with teacher assistance group and the teacherless Phyphox group revealed no significant difference (U = 437.000, Z = -0.193, p = .847). These findings indicate that while both Phyphox-assisted approaches yielded higher posttest rankings than the traditional method, the observed differences were not statistically significant.

The significant advantage observed in the Phyphox-assisted experimentation with the teacher-assistance group suggests that technology alone may not be sufficient to maximize conceptual learning. Rather, the effectiveness of mobile-assisted experimentation appears to depend on the quality of instructional scaffolding accompanying the technological intervention. During implementation, teacher facilitation involved guiding students through the experimental setup, prompting evidence-based reasoning, clarifying misconceptions, and helping learners connect empirical observations to theoretical principles of pendulum motion. These forms of scaffolding likely enabled students to construct more scientifically accurate explanations and a deeper conceptual understanding than independent experimentation alone could. Consequently, the findings support the view that mobile technologies function most effectively as pedagogical tools when integrated with purposeful teacher guidance rather than as stand-alone instructional solutions.

The findings are consistent with the study of Mazzella and Testa (2016), who reported that smartphone-assisted experimentation improves students' understanding of motion-related concepts by allowing them to engage directly in scientific investigations and analyze authentic experimental data. Likewise, research on guided inquiry learning suggests that teacher facilitation enhances the effectiveness of technology-supported instruction by helping students navigate complex concepts and develop deeper conceptual reasoning (Arceño & Mendaño, 2026).

Although statistically significant differences were observed between the traditional instruction group and the Phyphox-assisted experimentation with teacher assistance group, the practical significance of these differences should also be considered. The mean posttest score difference between the groups was relatively modest (1.94 points), suggesting that while teacher-assisted mobile experimentation provides measurable advantages, educational stakeholders should evaluate both statistical and instructional significance when considering large-scale implementation.

Overall, the results indicate that mobile-assisted experimentation using the Phyphox application can enhance students' conceptual understanding of pendulum motion. However, the significant difference observed only between the traditional instruction group and the Phyphox with teacher assistance group suggests that teacher guidance remains an important factor in maximizing the educational benefits of mobile-assisted learning environments.

CONCLUSIONS AND RECOMMENDATIONS

This study investigated the effects of traditional instruction, teacher-assisted Phyphox-assisted experimentation, and teacherless Phyphox-assisted experimentation on Grade 8 students' conceptual understanding of pendulum motion. The findings revealed that all three instructional approaches significantly improved students' conceptual understanding, indicating that each method contributed positively to learning. Furthermore, the absence of significant differences in pretest performance confirmed the comparability of the groups before the intervention.

Significant differences emerged in posttest scores, with students who received Phyphox-assisted experimentation with teacher assistance demonstrating superior performance compared with those receiving traditional instruction. However, no statistically significant differences were observed between the teacherless Phyphox group and the traditional instruction group or between the two Phyphox-assisted groups. These findings suggest that while mobile-assisted experimentation represents a promising instructional approach, its effectiveness may be enhanced when accompanied by teacher facilitation that supports data interpretation, conceptual clarification, and evidence-based reasoning.

While the findings demonstrate the educational value of Phyphox-assisted experimentation in improving students' conceptual understanding of pendulum motion, the results should be interpreted in light of the study's limitations. The research was conducted using a quasi-experimental design involving 90 Grade 8 students from a single public secondary school, which may limit the generalizability of the findings. Future research is recommended to include larger and more diverse samples from multiple schools, districts, and educational settings to strengthen the external validity of the results. In addition, longitudinal studies are encouraged to examine the long-term retention of conceptual understanding and determine whether the learning gains achieved through mobile-assisted experimentation are sustained over time. Researchers may also investigate the effectiveness of the Phyphox application and other smartphone sensor-based learning technologies across various science disciplines and physics topics, such as mechanics, electricity, waves, and thermodynamics, to establish their broader educational applicability. Finally, future studies may explore additional learner outcomes, including scientific reasoning, problem-solving skills, motivation, engagement, and attitudes toward science, to provide a more comprehensive evaluation of mobile-assisted learning in science education.

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