




 Research Article

Physics Practical Performance Through Differentiated Instruction: Insight into Senior High School Physics Practical Instruction in Ghana

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Abstract

Recurring challenges in the physics practical performance of Ghanaian Senior High School (SHS) students, particularly in basic experiments like the simple pendulum, warrant fresh pedagogical approaches. Differentiated Instruction (DI), which tailors instruction to different learner needs, is a promising yet unexplored strategy in this context. This study aimed to establish the learning needs of selected SHS students in performing the simple pendulum experiment and pinpoint some DI strategies that enhance their practical performance. A quasi-experimental design was employed involving 160 Form 2 physics students (97 males and 63 females) drawn from two intact classes in two senior high schools in Ghana. A structured questionnaire manifested significant learning issues: 78.7% of the students lacked a clear conceptualisation of the relationship between pendulum length and period, with recording time (28.8%), graphing results (24.4%), and period calculation (23.8%) being primary issues. Furthermore, 53.1% felt uneasy with mathematical equations, and 79.4% lacked confidence to conduct the experiment individually. The experimental group (n=80) received a four-week DI intervention. Regression analysis of post-intervention data indicated five DI strategies that predicted improved performance: hands-on experimentation ($\beta = 0.449$, $p < .000$), teacher modification of learning styles ($\beta = 0.192$, $p = .018$), decreased complexity of lessons ($\beta = 0.175$, $p = .022$), students feeling comfortable demonstrating knowledge via experiments ($\beta = 0.157$, $p = .025$), and offering choices for assignments ($\beta = 0.177$, $p = .016$). A Mann–Whitney U test revealed that the DI group achieved significantly higher post-test scores compared to the control group ($U = 3193.50$, $Z = -0.023$, $p = .982$), with a medium-to-large effect size ($r = .41$). The study concludes that senior high school students exhibit diverse learning needs in physics practicals, which can be effectively addressed through adaptable and flexible differentiated instructional approaches. It recommends integrating these evidence-based interventions into teacher education and curriculum design to improve physics practical performance.

Keywords: Differentiated Instruction, Ghana, Physics Education, Practical Performance, Senior High School, Simple Pendulum Experiment

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1. INTRODUCTION

Physics remains a backbone of the natural sciences since it forms the basis for technological advancements, scientific research, and problem-solving in other disciplines. Nevertheless, it is generally thought by students to be one of the most difficult courses owing to its theoretical nature, reliance on mathematics, and need for experimental precision (Adebisi et al., 2020; Sabasales, 2018). These issues tend to create misconceptions, ineffective conceptualisation, and ineffective application of theoretical concepts

to practical situations (Ugwuanyi et al., 2023). These factors eventually lead students to consider physics as highly theoretical and inaccessible, and this has a direct impact on their performance, especially in practical experiments where theory and experiment must be integrated.

Experimental work is central to physics learning as it comes to fill the gap between theory and practice. Experiments allow students to experiment with equipment, test hypotheses, and investigate physical phenomena, thereby reinforcing conceptual and procedural knowledge (Holmes & Wieman, 2018). Tamir (1977) corroborated by emphasising that science laboratory activities in science teaching have four basic functions: enabling students to comprehend abstract concepts; building analytical and problem-solving skills; raising practical skills; and encouraging good science attitudes. Follow-up studies validate that well-planned laboratory activities enhance higher-order thinking and promote scientific thinking, whereas poorly planned practical activities are not associated with learning advantages (Smale-Jacobse et al., 2019).

Chronic physics education issues in Ghana are amply documented. Predominant classroom instruction is teacher-centered with little inquiry or student-centered learning (Buabeng et al., 2014). This undue reliance on demonstrations and lectures hinders active participation and sustains the illusion that physics is for students who are mathematically gifted (Ugochinyere et al., 2024). The West African Examinations Council (WAEC) reports consistently have always pointed out the candidates' weak areas in experimental arrangement, accurate measurement, graphing, and theory application to practical (WAEC, 2021, 2022, 2023, 2024). For example, the 2023 report revealed that the majority of students failed to utilise metre-rule measurements correctly, poorly labeled graphs, and struggled with logarithmic calculations (Educative Newsroom, 2023). These persistent weaknesses indicate not only conceptual weaknesses but also experimental and data-handling weaknesses.

Structural problems exacerbate the issue further. The majority of Ghanaian schools lack decent laboratory facilities, high student-to-teacher ratios, and spasmodic availability of trained physics teachers (Aboagye & Avor, 2025; Antwi et al., 2021). Even in some schools where a laboratory exists, it typically goes unused or reserved for end-of-studies students as they prepare for examinations, with minimal opportunity for continuous practice. These systemic limitations contribute to the long-standing occurrence of poor performance exhibited in WAEC results (Scribd, 2023).

Conceding these limitations, researchers in Ghana and elsewhere have experimented with numerous innovative pedagogies. Problem-solving learning, inquiry-learning teaching, blended learning, and virtual labs have been shown to increase conceptual understanding, learner engagement, and laboratory skills (Babalola & Alabi, 2021; Akore et al., 2023; Antwi et al., 2021; Owusu & Antwi, 2022). International studies similarly place a premium on inquiry, scaffolding, and autonomy in fostering the scientific abilities of students (Smale-Jacobse et al., 2019). These are, however, resource-heavy, require teacher training, and pedagogic cultural shifts that are hard to achieve in the resource-constrained settings of Ghana.

DI has thus emerged as a feasible alternative to meet diverse learner needs in such settings. Characterised by Tomlinson (2001, 2014) as an accommodation of content, process, and product to the readiness, interest, and learning profiles of students, DI emphasises flexibility, ongoing assessment, and multiple routes to learning. Theoretically, DI is rooted in Constructivist Learning Theory (Piaget, 1970; Bruner, 1966), which posits that students construct knowledge themselves, and Vygotsky's (1978) Zone of Proximal Development, which emphasises scaffolding and social interaction. In practice, DI translates to tiered tasks, flexible grouping, adaptive pacing, and scaffolded support, and therefore it works for advanced learners as well as strugglers.

Empirical evidence confirms the effectiveness of DI in science learning. Smale-Jacobse et al. (2019) reported that DI produces inclusivity as well as better conceptual understanding. Abamba et al. (2024) demonstrated that DI, along with students' cognitive styles, significantly improved physics achievement. Developing countries face significant, well-documented challenges in science education, including inadequate infrastructure and a lack of trained teachers (Yoldere & Adamu, 2015). In response to such challenges, innovative pedagogies have been explored. For instance, Toledo (2023) found that incorporating multiple intelligences into teaching enhances science learning. Furthermore, research specifically on differentiated instruction (DI), such as that by Santoso et al. (2025), has shown that DI can outperform conventional teaching in boosting student achievement, motivation, and scientific competence.

Applied to physics experiments, DI holds the promise of tiering tasks, incorporating multimodal resources, and adjusting assessment types. For example, with the experiment on the simple pendulum, talented students can be tasked with deriving equations and conducting error analysis, but less able students can fill in template steps in the measurement of oscillations and graph plotting. This approach maintains rigour while ensuring equitable access to worthwhile learning.

In spite of its potential, DI usage in physics education in Ghana remains underexplored. While most interventions to date have revolved around problem-solving or inquiry methods, little empirical evidence has been amassed on whether DI can address repeated areas of experimental precision, data analysis, and comprehension noted in WAEC results. Further, the adaptability of DI usage in limited-resource Ghanaian classrooms has not been adequately investigated. This study addresses these gaps by empirically investigating the role of differentiated instruction in promoting the performance of SHS students in the simple pendulum experiment.

Specifically, the study pursued two objectives: (1) to identify differentiated instructional strategies that significantly enhance students' practical performance, and (2) to assess the general effectiveness of differentiated instruction over typical teaching practices.

2. METHODS

2.1. Research Design

This research used a quasi-experimental, non-randomised pre-test–post-test control group design. Two intact classes of senior high school students were purposively selected and randomly assigned to experimental and control groups. A pre-test created a baseline equivalence, and a post-test captured the effect of DI. The design allowed assessment of the causal effect of DI within real classroom environments, guaranteeing ecological validity.

2.2. Population and Sample

The target population comprised SHS physics students in Mampong Municipality and Sekyere Central, Ashanti Region, Ghana, specifically second-year students who had prior exposure to basic mechanics but limited experience with pendulum practical work. The sample comprised 160 Senior High School physics students, consisting of 97 males and 63 females. Participants were drawn from two intact classes selected through purposive sampling: 80 in the experimental group, taught with differentiated instructional strategies, and 80 in the control group, taught through conventional whole-class instruction. Both groups were similar in age (15–18 years) and had comparable exposure to the national physics curriculum. Although the sample was not perfectly gender-balanced, both male and female students were represented in each group, reducing the likelihood that gender composition alone accounted for observed differences in performance.

2.3. Research Instruments

Two instruments were used in the study. The Physics Practical Performance Test (PPPT), developed by the researcher, was used to assess students' performance in the simple pendulum experiment. Two equivalent parallel forms were constructed: PPPTa (pre-test) and PPPTb (post-test), to ensure comparability while minimising test–retest effects. Each form consisted of 12 items, comprising 10 multiple-choice items and 2 open-ended practical items.

The multiple-choice items assessed conceptual and procedural knowledge related to oscillation measurement, period calculation, graphical interpretation, and determination of gravitational acceleration, and were scored dichotomously (1 = correct, 0 = incorrect). The open-ended items assessed practical execution, data handling, calculations, and graphical analysis. These items were scored using a predefined analytic scoring rubric, with marks awarded based on accuracy, completeness, and correctness of procedures and explanations. The PPPT was administered under standardised test conditions, and participants were given 30 minutes to complete the instrument.

2.4. Validity and Reliability

The instruments were comprehensively validated and reliability checked prior to the main study. Face, content, and construct validity were established through expert review. Pre-testing of the instruments was conducted among 30 second-year physics students at Nsutaman Senior High School to render them clear, proper, and psychometrically fine-tuned. Reliability tests also showed high internal consistency of items on instruments. The Students' Attitude Questionnaire (SAQ) had a Cronbach's alpha of 0.943 (45 items), which is a high reliability. The multiple-choice item of the PPPT had a Cronbach's alpha of 0.739, which is an acceptable level of reliability. To ensure scoring objectivity for the open-ended items, responses were independently scored by two trained raters using the same scoring rubric. Inter-rater reliability was established using Cohen's Kappa, yielding a coefficient of 0.847, which indicates near-perfect agreement (Kottner et al., 2011).

2.5. Intervention Procedure

The entire study was carried out in three well-planned phases to make sure the researcher could take the same standardised practical test on the simple pendulum experiment. This first test helped the researchers find out how much the students already knew and could do before any new teaching approach was used. Both the experimental and control groups received the same total instructional time; however, only the experimental group was exposed to differentiated instructional strategies.

Phase 1: Pre-Intervention Assessment

In the first phase, a pre-test was administered to both the experimental and control groups using a standardized practical test on the simple pendulum experiment. The purpose of this assessment was to determine students' prior knowledge and practical skills before the implementation of the instructional intervention. The results of the pre-test served as baseline data for comparing students' performance before and after the intervention.

Phase 2: Differentiated Instruction Intervention

The differentiated instruction intervention lasted for four weeks and was aligned with the SHS Physics syllabus on the simple pendulum experiment. The intervention was implemented over a four-week period, with two instructional sessions conducted per week. Each session lasted approximately 90 minutes, resulting in a total instructional time of 12 hours for the differentiated instruction treatment. All sessions were delivered during regular physics practical periods to ensure consistency with the school timetable and to minimise disruption to normal classroom routines. While the control group was taught using conventional whole-class, lecture–demonstration methods, the experimental group received instruction explicitly differentiated in terms of content, process, and product, following Tomlinson's DI framework.

Differentiation of content was achieved by varying the level of conceptual depth and instructional materials provided to each subgroup. All students studied the same core topic (simple pendulum), but the materials differed in complexity. Subgroup A received enrichment materials and open-ended investigative prompts, Subgroup B received standard lesson notes with guiding questions, and Subgroup C received simplified notes, step-by-step guides, and visual aids.

Differentiation of process was implemented through tiered laboratory tasks, flexible grouping, and scaffolded support. During practical sessions:

Subgroup A worked largely independently, designing experiments, conducting multiple trials, deriving relationships (e.g., $T \propto \sqrt{L}$), and engaging in limited teacher consultation.

Subgroup B engaged in semi-structured laboratory activities, using guided worksheets and teacher prompts to measure oscillations, calculate periods, and plot graphs.

Subgroup C participated in highly scaffolded activities involving teacher-led demonstrations, peer support, pre-measured data sets, and guided calculations to reduce cognitive load.

Flexible grouping was maintained throughout the intervention, allowing students to work individually, in pairs, or in small groups depending on task demands and observed learning needs.

Differentiation of the product was realised through flexible assessment formats. Students were allowed to demonstrate understanding in multiple ways, including written laboratory reports, oral explanations, practical demonstrations, graphical analyses, or a combination of these. High-readiness students completed full laboratory reports with graph interpretation and calculation of gravitational acceleration, moderate-readiness students completed structured reports with prompts, and low-readiness students demonstrated understanding through practical execution checklists, simplified worksheets, and oral questioning.

Table 1. Content of Lesson Notes for the Experimental Group, Showing How Differentiation Was Implemented

Wks	Lesson Title	Content Standards	Indicators & Objectives	Teaching & Learning Activities (Differentiated)	Assessment Strategies	Resources/ Materials
1	Introduction to Simple Pendulum	SHS Physics Syllabus – Strand 3.11: Mechanics	Identify the components of a simple pendulum - Explain key concepts: period, amplitude, length, and oscillation	Subgroup A (High achievers): Independent lab setup and prediction tasks Subgroup B (Moderate): Guided discovery tasks Subgroup C (Low achievers): Step-by-step demonstration and peer support	Quiz (individualised per group), peer explanation, practical worksheet	Pendulum setup kits, stopwatches, measurement tapes
2	Measurement of Time & Period	SHS Physics Syllabus – Strand 3.11.2	Measure the time for multiple oscillations - Calculate the period and frequency	Subgroup A: Inquiry-based lab measuring multiple trials and averaging results Subgroup B: Use of digital timers with scaffolding Subgroup C: Use of pre-measured times and teacher-assisted calculations	Group presentations, time recording and accuracy check	Stopwatch Timer app Graphs of time vs oscillation
3	Effect of Length on Period	SHS Physics Syllabus – Strand 3.11.2	Investigate the relationship between the length and period of a pendulum	Subgroup A: Open investigation and derive $T \propto \sqrt{L}$ Subgroup B: Semi-structured experiment Subgroup C: Fixed-length changes, guided observation	Lab report, Observation checklist, Concept map	String Retort stands Meter rules
4	Graphical Analysis & Conclusion	SHS Physics Syllabus – Strand 3.11.2	Plot T^2 vs L graph - Interpret slope to calculate g	Subgroup A: Full graph plotting and analysis Subgroup B: Structured data plotting with partial guidance Subgroup C: Use of grid sheets and peer walkthroughs	Graph interpretation Group discussion	Graph sheets, Calculators, Markers

Phase 3: Post-Test and Student Feedback

After completing the four-week intervention program, both groups were administered the post-test (PPPTb) to determine the learning gains in the performance component. The students in the experimental group additionally filled out the Students’ Attitude Questionnaire (SAQ) regarding their experiences with the different learning strategies.

The fact that the differentiated instruction strategy is structured and systematic ensures that this process can be replicated within similar senior high school physics settings through administering a diagnostic pre-test, dividing learners into groups based on readiness, adopting tiered laboratory activities related to general learning goals, and making use of versatile methods of assessment.

2.6. Ethical Procedures

Approval was obtained from my university’s ethics committee, and permission was granted from the school authorities. Informed and parental consent were secured, participation was voluntary, and confidentiality and anonymity were assured.

2.7. Data Analysis

Quantitative data of SAQ and (PPPTa and PPPTb) were processed using SPSS software version 23. Student attitude and performance were described by means, frequencies, and standard deviations. The Mann–Whitney U test was employed in inferential analysis to test pre-test group equivalence since data were not normal, thus not satisfying a parametric test assumption. Similarly, Mann–Whitney U testing was employed to find differences in post-test performance between the control and experimental groups, as post-test data also showed significant deviation from normality. Moreover, the treatment effect size was calculated using the effect size statistic *r*, which also provided information about the practical significance of differences found.

All statistical tests were conducted at a significance level of $\alpha = .05$. Results with $p < .05$ were considered statistically significant, while $p < .01$ indicated strong statistical significance.

Table 2. Students’ Agreements with Differentiated Instructional Strategic Experiences That Enhance Practical Performance in the Simple Pendulum Experiment

Item	Strongly Disagree F(%)	Disagree F(%)	Agree F(%)	Strongly Agree F(%)
1. Using different materials like textbooks, notes, and visual aids helps me understand physics theory better.	0 (0.0)	21 (26.3)	39 (48.8)	20 (25.0)
2. Content delivery methods like textbooks, visuals, and hands-on experiments help me understand physics concepts better.	0 (0.0)	4 (5.0)	23 (28.7)	53 (66.3)
3. I find it easier to learn when content is broken into smaller steps.	0 (0.0)	18 (22.5)	29 (36.3)	33 (41.3)
4. It is effective when teachers adjust lesson complexity based on my understanding.	0 (0.0)	10 (12.5)	28 (35.0)	42 (52.5)
5. Additional resources like simplified notes, extra materials, simulations, or step-by-step guides help me understand physics practical work better.	0 (0.0)	18 (22.5)	40 (50.0)	22 (27.5)
6. I prefer working individually, in groups, or with demonstrations /peer assistance during physics practical lessons.	0 (0.0)	1 (1.3)	32 (40.0)	47 (58.8)
7. I actively engage in discussions during physics practical lessons.	0 (0.0)	20 (25.0)	38 (47.5)	22 (27.5)
8. Hands-on experimentation helps me understand physics concepts better.	0 (0.0)	14 (17.5)	33 (41.3)	33 (41.3)
9. My teacher adapts teaching approaches to match my learning style.	0 (0.0)	6 (7.5)	20 (25.0)	54 (67.5)
10. I find my preferred learning style (visual, auditory, kinesthetic, reading/writing) useful for physics practical work.	0 (0.0)	20 (25.0)	40 (50.0)	20 (25.0)
11. I prefer demonstrating my understanding through written, oral, practical, or visual presentations.	0 (0.0)	0 (0.0)	27 (33.8)	53 (66.3)
12. I feel comfortable demonstrating my understanding through hands-on experiments.	0 (0.0)	1 (1.3)	28 (35.0)	51 (63.7)
13. Practical exams, projects, or other assessments help me show my knowledge best.	0 (0.0)	17 (21.3)	39 (48.8)	24 (30.0)
14. Having assignment options (practical vs. written) improves my performance.	0 (0.0)	14 (17.5)	36 (45.0)	30 (37.5)
15. Flexibility in assessment methods is important to me.	0 (0.0)	1 (1.3)	21 (26.3)	58 (72.5)

Data Source: Field Data, 2025

3. RESULTS

3.1. Differentiated Instructional Strategies and Students’ Practical Performance

Table 2 indicates the levels of agreement of students with DI practices that enhance their hands-on performance in the simple pendulum experiment. The general responses indicate very positive attitudes

towards DI practices. For usage of mixed resources, no student disagreed strongly, but 21 (26.3%) disagreed, 39 (48.8%) agreed, and 20 (25.0%) agreed strongly that the use of various materials, such as books, notes, and visual aids, improved their understanding of physics theory. Similarly, for presentation of content in more than one mode (textbooks, pictures, experiments, or lectures), only 4 (5.0%) disagreed, while 23 (28.7%) agreed, and a huge majority of 53 (66.3%) agreed strongly. Dividing content into manageable steps was deemed effective by 62 students, 29 (36.3%) of whom agreed, while 33 (41.3%) strongly agreed, even though 18 (22.5%) disagreed. Additionally, 70 students, 87.5%, agreed or strongly agreed that varying lesson complexity to the level of their understanding was effective, with 10 (12.5%) only disagreeing.

The majority of them, 62 students (77.5%), preferred utilisation of other materials such as simplified notes, additional materials, and simulation, whereas 18 (22.5%) did not. For the most optimal learning interactions, almost all the students preferred adaptable modes: just 1 (1.3%) did not agree, 32 (40.0%) agreed, and 47 (58.8%) strongly agreed that they learned from individual work, group work, or from help by peers.

Upon being asked whether they participated in discussions during practice classes, 60 students (75.0%) responded in the affirmative, 38 (47.5%) of whom agreed, and 22 (27.5%) strongly agreed. Likewise, 66 students (82.6%) agreed that experimenting practically enhanced their understanding of physics principles, of which 33 (41.3%) agreed, and 33 (41.3%) strongly agreed. Accommodation of teachers to learning styles was best valued, with 74 students (92.5%) in accord, 20 (25.0%) agreed, and 54 (67.5%) strongly agreed, and just 6 (7.5%) disagreed. Similarly, most students (65, or 81.3%) admitted the utility of their preferred learning styles (visual, auditory, kinesthetic, or reading/writing) utilised during physics practical work. Flexible assessment practices were favoured strongly. All the students (100%) concurred or strongly concurred that they enjoyed demonstrating understanding in diverse ways: 27 (33.8%) concurred, and 53 (66.3%) strongly concurred. Further, 79 students (98.7%) were at ease demonstrating knowledge in experiments. Practical examinations in the form of experiments and projects were supported by 63 students (78.8%), with 39 (48.8%) agreeing and 24 (30.0%) strongly agreeing. Assignment preference was also essential: 66 students (82.5%) agreed or strongly agreed that options (written versus practical) improved performance. Finally, flexibility in methods of assessment received the highest support, at 79 (98.8%), in agreement, 21 (26.3%) agreed, and 58 (72.5%) strongly agreed.

To further examine the predictive power of DI strategies, a multiple regression analysis was conducted with post-test scores as the dependent variable. The ANOVA summary (see Table 3) showed that the regression model was significant, $F(15, 64) = 15.69, p < .001$, explaining 79% of the variance in students' performance.

Table 3. ANOVA Summary for the Effect of DI Strategies on Practical Performance

Source	SS	df	MS	F	Sig.
Regression	605.760	15	40.384	15.690	.000
Residual	164.728	64	2.574		
Total	770.487	79			

Note. Dependent variable = Post-test score. Predictors = differentiated instructional strategies (e.g., flexible assessment, hands-on experimentation, multimodal learning, scaffolding, etc.).

From the data in Table 4, five strategies emerged as significant predictors: adjusting lesson complexity ($\beta = .175, p = .022$), hands-on experimentation ($\beta = .449, p < .001$), teacher adaptation to learning styles ($\beta = .192, p = .018$), confidence with experiments ($\beta = .157, p = .025$), and assignment options ($\beta = .177, p = .016$).

Table 4. Significant Predictors of Students' Practical Performance

Predictor (DI Strategy)	B	T	Sig.
Adjusting lesson complexity	.175	2.348	.022
Hands-on experimentation	.449	4.592	.000
Teacher adapts to learning style	.192	2.418	.018
Comfort with hands-on experiments	.157	2.302	.025
Assignment options (practical/written)	.177	2.486	.016

Of these, experiential experimentation was the strongest predictor, highlighting the dominant role of experiential learning in promoting students' performance in practical work. Adaptive teaching, scaffolding through complexity of lessons, and adaptive assessment were also key predictors, and this suggests that personalisation and learner-centred interventions are key drivers of improved performance in physics practical work.

3.2. Effectiveness of Differentiated Instruction on Practical Performance

Normality tests were carried out for both control and experimental groups' pre-test and post-test scores to determine normality in order to decide whether to apply parametric or non-parametric statistical analysis. The results are shown below in Table 5.

Table 5. Tests of Normality for Pre-Test and Post-Test Scores by Groups

	Group	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Pre-Test Score	Expt.1	.127	80	.003	.975	80	.119
	Ctrl. 2	.158	80	.000	.955	80	.007
Post-Test Score	Expt.1	.116	80	.010	.950	80	.003
	Ctrl 2	.191	80	.000	.935	80	.001

a. Lilliefors Significance Correction

Table 6. Mann–Whitney U Test Comparing Pre-Test Scores of Experimental and Control Groups

	Pre – Test Score
Mann-Whitney U	3193.500
Wilcoxon W	6433.500
Z	-.023
Asymp. Sig. (2-tailed)	.982
Exact Sig. (2-tailed)	.983
Exact Sig. (1-tailed)	.491
Point Probability	.001

a. Grouping Variable: Group

The Shapiro-Wilk test revealed that experimental group pre-test scores did not significantly differ from normality ($W = .975, p = .119$), but control group pre-test scores ($W = .955, p = .007$) and post-test scores for both groups ($p < .01$) were not normally distributed. Mann–Whitney U test (see Table 6) was therefore used to compare pre-test scores.

Results in Table 6 did not show any significant difference between the control and experimental groups' pre-test performance ($U = 3193.50, Z = -0.023, p = .982$). This finding suggests that the two groups were at par with their baseline performance at the beginning, prior to intervention.

After intervention, descriptive statistics (see Table 7) showed that the experimental group ($M = 15.38, SD = 3.16$) scored significantly greater than the control group ($M = 12.99, SD = 1.44$).

Table 7. Descriptive Statistics of Post-Test Scores for Experimental and Control Groups

Group	N	Mean	Std. Deviation	Std. Error Mean
Experimental	80	15.38	3.156	.353
Control	80	12.99	1.436	.161

A Mann–Whitney U test was employed to determine whether there existed a significant difference in post-test performance between the experimental group taught through DI and the control group taught through traditional instruction.

Data in Table 8 showed that there was a statistically significant difference between groups, $U = 1691.00, Z = -5.19, p < .000$, with effect size $r = .41$. This represents a medium-to-large effect and means that students in the experimental group, who were taught using differentiated instruction, performed significantly better on the post-test than students in the control group, who were taught using regular

instruction. The result indicates that the instructional treatment was statistically and practically meaningful in improving the practical performance outcomes of the students.

Table 8. Mann–Whitney U Test Comparing Post-Test Scores of Experimental and Control Groups

	Post-Test Score
Mann-Whitney U	1691.000
Wilcoxon W	4931.000
Z	-5.194
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Group

4. DISCUSSION

This study examined the effects of DI on senior high school students' performance in the simple pendulum experiment, focusing on strategies that enhance practical learning and comparing DI with traditional instruction. The findings indicate strong student endorsement of differentiated practices and show that hands-on experimentation, lesson complexity adjustment, accommodation of learning preferences, and flexible assessment significantly predicted improved performance. Students taught using DI also outperformed their peers in the control group, with a medium-to-large effect size ($r = .41$), indicating both statistical and educational significance.

The positive effects of differentiated instruction may stem from the active, experiential, and procedural aspects inherent in physics practical activities. Student responses suggest that multimodal resources, scaffolded instruction, and flexible grouping reduced cognitive overload and supported gradual knowledge construction. The simple pendulum experiment requires coordination of measurement, timing, calculation, and graphical interpretation—tasks that can be challenging when instruction is uniform and fast-paced. By breaking tasks into manageable steps and allowing multiple entry points, DI enabled students to construct understanding progressively rather than merely follow procedures. This explanation aligns with constructivist learning theory, which emphasises learning through active engagement and appropriate scaffolding (Piaget, 1970; Vygotsky, 1978), and with evidence that scaffolded instruction enhances experimental reasoning (Smale-Jacobse et al., 2019).

Hands-on experimentation emerged as the strongest predictor of practical performance, which can be attributed to its role in strengthening procedural fluency and conceptual linkage. Differentiated instruction increased opportunities for students to manipulate apparatus, repeat measurements, and correct errors, thereby reinforcing essential laboratory skills. Holmes and Wieman (2018) argue that meaningful interaction with experimental processes is critical for effective laboratory learning, providing a theoretical basis for the dominant predictive role of hands-on experimentation observed in this study.

The significant contribution of lesson complexity adjustment and teacher adaptation to learning preferences can be explained by variation in students' prior knowledge and cognitive readiness. Students enter physics practical lessons with differing levels of mathematical confidence and experimental experience. By tailoring task difficulty and pacing, DI ensured that weaker students received sufficient support while more advanced learners remained appropriately challenged. Tomlinson (2014) emphasises that instruction aligned with learner readiness enhances achievement by preventing disengagement and frustration, a mechanism consistent with the observed findings.

Flexible assessment practices also contributed to improved performance. Traditional written assessments may disadvantage students who understand experimental concepts but struggle with symbolic manipulation. Providing options for demonstrating understanding through practical tasks or alternative representations likely enhanced confidence and motivation while improving assessment validity. This interpretation is supported by Ugochinyere et al. (2024), who found that learner-centred assessment promotes engagement and achievement.

Although the findings demonstrate strong effects, prior research indicates that differentiated instruction does not always yield consistent outcomes. Studies reporting mixed results often attribute weaker effects to superficial implementation or insufficient teacher preparation (Smale-Jacobse et al., 2019; Buabeng et al., 2014). In the present study, the structured design of the intervention, combined with continuous scaffolding and feedback, likely contributed to its effectiveness.

The significant post-test difference between experimental and control groups further supports this interpretation. Both groups were comparable at baseline, yet the experimental group achieved significantly higher scores after the four-week intervention. The medium-to-large effect size ($r = .41$) not only indicates statistical significance but also a substantial practical effect, resonating with prior evidence that differentiated instruction yields stronger learning gains than traditional teacher-centred methods when instruction is responsive to learner diversity (Santoso et al., 2025; Smale-Jacobse et al., 2019). The magnitude of the effect may also reflect the focused nature of the intervention, which targeted a specific practical task and allowed sustained engagement with core skills.

These findings are particularly relevant in the Ghanaian context, where WAEC Chief Examiner's reports consistently identify weaknesses in experimental setup, measurement accuracy, and graph interpretation (WAEC, 2023). Integrating scaffolded, hands-on, and flexible instructional strategies, differentiated instruction directly addressed these challenges. The results, therefore, align with Ghanaian studies demonstrating that student-centred pedagogies improve physics performance (Owusu & Antwi, 2022; Antwi et al., 2021). Unlike some approaches, however, DI explicitly accommodates learner variability within the same classroom, making it especially suitable for heterogeneous and resource-constrained environments.

Nevertheless, differentiated instruction requires careful planning, sustained teacher commitment, and effective classroom management, which may be challenging in overcrowded classrooms. These constraints help explain inconsistent findings in some prior studies and underscore the importance of context-sensitive implementation.

5. PRACTICAL IMPLICATIONS

The study highlights that DI should be deliberately embedded in physics laboratory lessons through strategies such as hands-on experimentation, scaffolded learning, adaptive pacing, and flexible assessment. Teachers can thereby support learners of varying readiness levels in developing core skills like measurement, graphing, and data analysis. Policymakers and curriculum planners are encouraged to integrate DI principles into physics curricula by providing space for tiered activities, multimodal resources, and alternative assessments to address persistent weaknesses identified in WAEC Chief Examiner's reports. Teacher training and professional development should also emphasise DI pedagogy, equipping educators with tools for managing heterogeneous classrooms effectively. Importantly, in resource-constrained contexts such as Ghana, DI offers a cost-effective means of enhancing laboratory experiences and improving physics performance without requiring major infrastructural investments.

6. CONCLUSION

Students highly rated DI strategies such as hands-on experimentation, scaffolded tasks, flexible grouping, adaptive pacing, and multimodal resources. Regression analysis showed that five strategies (hands-on experimentation, lesson adjustment, teacher adaptation to learning styles, confidence with experiments, and assignment options) were performance predictors. Comparisons between the experiment and control groups also showed that DI led to significantly higher post-test scores with a medium-to-large effect size ($r = .41$), which confirmed both statistical and learning gains. The outcomes support constructivist and sociocultural theories asserting active learning, scaffolding, and teacher mediation. The study indicates that DI meets varied learning requirements, enhances experiential performance in physics, and offers a solution to resource-constrained contexts like Ghana. It requires integrating DI into teacher education, curriculum development, and classroom pedagogy to stimulate attainment and enthusiasm in science education.

7. RECOMMENDATIONS

The study recommends that physics teachers integrate differentiated instructional methods into laboratory work, like hands-on experiments, scaffolding, pacing adaptations, flexible assessment, and multiple forms of resource usage, such as diagrams, simulations, and discussion with peers. Feedback and

assessment need to be diversified as well to allow students to display understanding in more than one way (verbally, through writing, through practical work, or project-based). On the training and policy aspects, teacher training programmes need to incorporate DI as core pedagogy with emphasis on its application in physics practical work. In-service training and workshops are necessary for ongoing professional learning, whereas curriculum developers need to incorporate tiered tasks and scaffolded experiments to assist different levels of readiness. More research is recommended for generalising DI to other fields of study, like chemistry and biology, for exploring long-term effects on retention and problem-solving, and for investigating the application in resource-poor classrooms common in Ghana.

8. LIMITATIONS

There are some limitations of this study. Quasi-experimental design resulted in random assignment not being feasible, constraining the generalisability of findings. It only tested the simple pendulum experiment and did not test whether differentiated instruction works in other physics lessons and in science in general. The short intervention time assessed only immediate outcomes, failing to measure long-term impacts on retention or problem-solving. In addition, teacher style and classroom environment may also have influenced results, and the sample used was only two schools in the Ashanti Region, as it is not generalisable. The findings are good indications of the worth of differentiated instruction and a starting point for further research in broader settings, nonetheless.

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