AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

EFFECT OF DIFFERENTIATED INSTRUCTION ON SENIOR HIGH SCHOOL PHYSICS STUDENTS' PRACTICAL PERFORMANCE IN SIMPLE PENDULUM

MUSTAPHA ISSAHAKU

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BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis, with the exception of quotations and references contained in published works which have been duly acknowledged; is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: Mustapha Issahaku

Signature: …… Date: ……

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

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May God richly bless you all.

DEDICATION

This work is dedicated to the Almighty God, whose grace and guidance have sustained me throughout this academic journey.

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ABSTRACT

The study examined the effect of differentiated instruction (DI) on the practical performance of Senior High School Students in physics in Ghana with specific reference to the simple pendulum experiment. In the midst of the primacy of practical work in learning in physics, the majority of the students still lack concept understanding, procedural accuracy, and data analysis skills, which reflect negatively in their test performance. Grounded in Constructivist Learning Theory and Vygotsky's Zone of Proximal Development, the study employed a quasi-experimental design with two intact classes. The experimental class (n = 80) received instruction according to their readiness, learning style, and interests, while the control class (n = 80) received instruction via traditional uniform methods (One-size-fits-all instructional approach). Data were collected by means of pre-tests, post-tests, and structured questionnaires on student achievement, learning needs, and attitudes towards DI. Statistical analyses (normality tests and Mann–Whitney U) indicated no differences at pre-test, but at post-test a significant advantage emerged for the experimental group, $U = 1691.00$, $Z = –5.19$, $p < .001$, with a medium-to-large effect size ($r = .41$). Very positive attitudes towards DI were registered on the part of the students, enjoying practices such as hands-on experimentation, adaptive task difficulty, multimodal presentation, step-by-step guidance, flexible assessment, and immediate feedback. The findings indicate that DI enhances physics practical performance through addressing diverse learning needs, fostering engagement, and bridging the theory–practice gap. The study recommends the integration of DI into teacher training, investment in practical work equipment, and the promotion of student-centred pedagogies in Ghanaian science education, particularly in resource-constrained environments.

CHAPTER ONE

INTRODUCTION

1.0 Overview

Overview of the chapter describes the background of the research and statement of the research problem. In addition, the research purpose of the study, the study questions of the research, the importance of the research, delimitation and limitation of the research are highlighted.

1.1 Background to the Study

Physics, though a foundational science, is often perceived as difficult by students because of its abstract concepts and reliance on complex mathematical reasoning (Sabasales, 2018; Adebisi et al., 2020; Taangahar & Okwori, 2022; Erinosho, 2013; Zammit & Cachia, 2019). Students' difficulties in understanding physics concepts tend to create deep, persistent misconceptions. Interventions based on conceptual change models have been shown to improve both understanding and confidence (Ugwuanyi et al., 2023). To counter this, academics argue that it is essential to provide concrete, real-life illustrations for simplifying complicated ideas and bridging the theory-practice divide (Kidega & Zheng, 2024; Scarparolo, & MacKinnon, 2022). The complexity of the subject can diminish students' engagement and motivation, making it essential for teachers to implement strategies that sustain interest and enhance learning outcomes (Kidega & Zheng, 2024). The abstract nature of many physics concepts makes it difficult for students to relate theoretical knowledge to real-life applications, often limiting their understanding and interest (Holmes & Wieman, 2018). It is for this reason that there is growing consensus among researchers on the need for teaching strategies that help learners associate the dots between such abstract

theories and practical applications, making the subject matter more relevant and effective (Peralta et al., 2025).

Recent studies in Ghana show that laboratory work has a great impact on students' academic performance, scientific process skills, and attitudes towards Physics. In one study of fifty Form Two students studying physics in a senior high technical school within the Eastern Region of Ghana, after interventions involving work on selected topics in electricity through practical work, not only did students gain better achievement (post-intervention tests), but also demonstrated enhanced attitudes and scientific process skills' acquisition Amponsah et al. (2018). This is concordant with the notion that working in the laboratory helps bridge the theory-practice gap, and makes it easier to have a clearer view of abstract concepts. (Antwi et al., 2021). Another study analysed senior high school physics teaching in Ghana and concluded that teaching in the classroom remains predominantly teacher-centered with minimal support for inquiry-based learning, which is regularly linked to practical work (Owusu et al., 2010).

They argued that such teacher-directed pedagogy limits conceptual change, i.e., the ability of students to test misconceptions or explore phenomena deeply, which is enabled by practical experiments. They recommend increased teachers' exposure to effective pedagogies, which integrate practical laboratory practice to enable learning (Buabeng et al., 2014). In another more recent foreign study, a re-designed, scaffolded first-year physics laboratory curriculum showed that altering the roles of instructors (from mere purveyors of theory to facilitators of student choice and group work) helped dramatically improve students' experimental abilities and more expert-level ways of thinking (Holmes et al., 2018).

Clear, measurable objectives were set in this study, activities and assessments were modified, and students provided more autonomy in the laboratory. The findings confirm that if laboratory work is not just demonstration but involves genuine practice and student agency, more profound learning takes place (Smale-Jacobse et al., 2019). And in virtual laboratory and simulation research, practical or quasi-practical experience has been shown to enhance the learning of physics theory, especially where there are no physical laboratories.

For example, a study in Nigeria found that secondary school students using virtual physics laboratories performed better than their peers using traditional laboratories in conceptual understanding and linked abstract theoretical content with tangible phenomena more effectively (Babalola & Alabi, 2021). In Ghana, case studies have found that pedagogic approaches that include the combination of theory and practical work such as problem-solving strategies, regular testing in-class, hands-on or demonstration tasks lead to higher student engagement, better performance, and reduced misconceptions. For instance, the enhancement of the performance and interest of physics students in kinematics by applying problem-solving and regular testing were found to enhance significantly from pre- to post-intervention means and enhanced student participation (Akore et al., 2023). All the Chief Examiners' Reports of West African Examinations Council (WAEC) Physics for 2021 to 2024 indicate recurring issues leading to poor candidate performance.

Over the years, candidates have struggled to record measurements correctly, plot and interpret graphs, handle logarithmic values, and draw deductions from experimental results. Many others misapply scientific concepts, confuse units, and are deficient in simple areas of mechanics, heat, and electricity, and simple concepts of potential difference and

electromotive force. These are signs of both procedural deficiency and knowledge deficiency in data-handling and reporting experiments. Additionally, systemic issues of poor laboratory facilities, patchy supervision, and limited practice in schools contribute to the problem. Collectively, these findings reveal that poor control of conceptual knowledge, poor practical training, and structural barriers in schools continue to reduce the performance of students in Physics in the West African Senior School Certificate Examination (WASSCE) (WAEC, 2021; 2022; 2023; 2024; Educative Newsroom, 2023). Experiments remain at the center of science education because they move learning from naked description to observable method, allowing for students to test claims, encounter misconceptions, and build enduring understanding.

Current quasi-experimental studies in Ghana found that well-planned hands-on activities in electricity topics had quantifiable gains in student performance, improved learning of scientific process skills, and more favourable physics attitudes; reinforcing the traditional contention that experimental laboratory work consolidates conceptual knowledge and students' orientation toward the subject (Antwi et al., 2021). Tamir (1977) determined the following objectives for the use of laboratories in science instruction. According to Gkioka (2020), modern physics laboratory instruction aims to develop students' laboratory skills, improve scientific reasoning and conceptual understanding, and foster positive attitudes toward science through hands-on and inquiry-based experiments.

Aside from achievement, international studies reveal that the majority of secondary students cannot manage the specific thinking skills to render practical work effective — namely, interpreting experimental data, identifying key graph characteristics (slope, intercept), and using appropriate scientific vocabulary when communicating results.

Holmes and Wieman (2018) argue that one of the major reasons laboratory activities often fail to deliver expected learning gains is that students struggle with data analysis and interpretation. They recommend that practical work be structured with clear scaffolds that promote reasoning about data, rather than focusing narrowly on apparatus manipulation. Laboratory reform research today conveys the same message: mere equipment provision or demonstration is not enough. Laboratory redesigns that define specific learning objectives for laboratories, steer student decision making, and put teachers in an inquiry facilitator role have been shown to produce larger gains in experimental skills and more "expert-like" thinking than stand-alone teacher demonstrations (Smale-Jacobse et al., 2019).

This line of scholarship shows that authentic, scaffolded inquiry and unobfuscated assessment of laboratory findings are essential if laboratory work is to deliver the cognitive and affective dividends hoped for in physics education (Smale-Jacobse et al., 2019; Holmes & Wieman, 2018). Differentiated instruction (customising tasks, pacing, and accommodations according to learners' varying readiness and learning profiles) has increasing empirical support as a strategy to make laboratory work more equitable and effective. Current applied studies and overviews show that while teachers employ varied entry points, cumulative supports, and diverse demonstration or assessment routes in science classes, student performance and engagement improve across various classrooms (Smale-Jacobse et al., 2019; Tomlinson & Moon, 2013).

That is, the accommodation of practical tasks (e.g., simplified arrangements for novices, extended investigation for specialists, and explicit data-analysis scaffolds for those who need them) makes possible the learning of procedural knowledge and conceptual understanding by more students. Empirical verification from African contexts mirrors these

international results. Practice-based versus expository instruction comparisons in Rwandan and Ghanaian secondary schools identify larger learning gains for practice-based teaching, whereas Ghanaian field studies indicate that frequent, well-supervision practical sessions are correlated with enhanced pupil performance and positive attitudes towards Physics (Antwi et al., 2021).

Yet most schools still rely on teacher-driven lessons or limit practical work largely to the last years, shortening students' opportunities to develop the hands-on and data-analytic skills behind eventual success in Science, Technology, Engineering and Mathematics (STEM) subjects (Buabeng et al., 2014). Infrastructure and teacher professional development remain central to the limiting factors. Studies of Ghanaian senior high schools reveal that having and utilising effective laboratories on a regular basis and continuous teacher training are most closely related to enhanced teacher commitment and better student performance in experimental science (Buabeng et al., 2014; Kidega & Zheng, 2024).

Where laboratory rooms are underutilised or laboratory sessions aren't regularly scheduled, students miss several scaffolded practices and thus fail to learn the procedural fluency and habits of mind for science that experiments should provide. These findings reinforce call demands for policy attention to long-term investment in resources for laboratory spaces and continuous professional development for physics instructors (Kidega & Zheng, 2024; Musah et al., 2025).

1.2 Statement of Problem

Elective science subjects at the senior high school (SHS) level in Ghana are Biology, Chemistry, and Physics. Of all of them, poor students' performance has been the case with

Physics, and specifically in the theory component of the subject, more than the others (WAEC, 2023). Historical WAEC data show that from 2003 to 2005, 13,067 (39.5%) of 33,043 candidates passed (A–D) in Physics, and from 2006 to 2009, 41,973 of 88,294 candidates (≈47.5%) had pass marks (A1–C6) (Scribd, 2023). This long-standing trend of poor performance is duplicated in more recent WAEC Chief Examiners' reports, which in the past decade have persisted in reporting challenges in Paper 2 and Paper 3 (the practical papers), including abuse of SI units, incorrect graph plotting, incorrect recording of measurements, and poor ;understanding of basic experimental concepts (WAEC, 2021; 2022; 2023, 2024). The 2023 report specifically observed that students failed to write metre-rule measurements to one decimal place, presentation of data, plotted graphs incorrectly, and did not record log T to three significant figures (Educative News Room, 2023).

Empirical evidence substantiates these concerns. Antwi et al. (2021) demonstrate that experiential hands-on learning appreciably improves learners' scientific process skill acquisition, while Owusu and Antwi (2022) demonstrate that problem-based learning approaches facilitate conceptual grasp of gravitational physics. Antwi et al. (2021) further confirms that the integration of problem-solving approaches with continuous assessment improves interest and performance in courses such as kinematics. However, foundational experimental skills remain in limited supply, as shown by repeated shortages in national examination materials (WAEC, 2023).

Ugochinyere et al. (2024) describe students' perception of physics as too mathematical and challenging; further remark that pedagogy is often very teacher-dominated, which may imply that practical work may be relegated in relative importance to theory in the perception of some teachers and students. Kidega and Zheng (2024) note that teachers and students in

Ghana's SHSs both view resource constraints (particularly inadequate laboratory equipment), teacher factors and attitudes of students as major hindrances to the effective teaching of physics. Similarly, Antwi et al. (2021) identify poor laboratory facilities, low trained physics teachers, and students' negative attitudes towards physics as a very mathematical subject as long-standing challenges to effective teaching of physics in Ghanaian senior high schools.

Although these studies provide valuable insights into the general issues of physics education in Ghana, they do not adequately address instructional models that can mitigate these issues within the context of resource-poor environments. Differentiated Instruction (DI) is largely unexplored in Ghanaian physics education, particularly its application in introductory experiments such as the simple pendulum. The pivotal position of experimental activities in cultivating conceptual understanding and scientific skills among SHS students is well documented (Akore et al., 2023; Buabeng et al., 2014). Yet few studies have examined how DI can enhance practical achievement, particularly in the Ashanti Mampong enclave.

The consecutive poor WASSCE performances in practical physics papers and the recurring demand for practical proficiency by WAEC (2021; 2022; 2023; 2024) highlight the need to establish evidence-based solutions to Ghana's context-specific learning difficulties, such as high student-teacher ratios, poor infrastructure, and teacher distribution imbalances. This study, therefore, seeks to evaluate the efficacy of DI in students' performance in simple pendulum experiments. Specifically, it examines the null hypothesis (H_0) of no difference in the performance of students instructed with DI and those instructed with conventional teaching. In so doing, the study addresses a pressing lacuna in the literature by investigating

the viability and efficacy of DI under resource-scarce conditions, thereby informing more context-sensitive interventions to improve physics education in Ghana.

1.3 Purpose of the Study

The main purpose of the study was to assess the effect of DI on senior high school physics students' practical performance in simple pendulum.

1.3.1 Specific Objectives of the Study

Specifically, the study sought to:

1. Identify the varying learning needs of senior high school physics students in a simple pendulum experiment.
2. Identify specific differentiated instructional strategies that positively impact the practical performance of senior high school physics students in simple pendulum experiments.
3. Assess the students' attitude towards DI in the physics laboratory setting.
4. Assess the effectiveness of DI in improving the practical performance of senior high school physics students in simple pendulum.

1.4 Research Questions of the Study

1. What are the varying learning needs of senior high school physics students when conducting a simple pendulum experiment?
2. What specific differentiated instructional strategies contribute significantly to improving senior high school physics practical performance in the simple pendulum experiment?
3. What are the attitudes of students towards DI in the physics laboratory setting?

1.5 Research Hypothesis

Ho: There is no statistically significant difference in the practical performance of senior high school physics students who received DI and those who received traditional instruction in the simple pendulum experiment.

Ha: There is a statistically significant difference in the practical performance of senior high school physics students who received DI and those who received traditional instruction in the simple pendulum experiment.

1.6 Significance of the Study

The relevance of the study lies in its ability to supply answers to essential questions in teaching and learning physics laboratory sessions, particularly in areas where students have consistently been performing dismally. Investigating the specific effect of DI on the practical skills of the students in topics like Optics and Simple Harmonic Motion, the study presents empirical data to guide the development of effective instructional methods founded on students' differing learning demands.

To educators, the findings offer pragmatic understanding of how pedagogy can be adjusted to make students more engaged and responsive to conceptual understanding in Physics. The study ascertains the role of personalised pedagogy in facilitating critical thinking, problem-solving skills, and hand-on experience, leading to overall academic success in Physics.

The findings of this research can be utilised by educational policymakers to make their policy choices and policy alternatives concerning educational reforms and education policies. Knowing the impact of DI, policymakers are now able to formulate policies that facilitate and enhance more student-centered and DI strategies.

This study contributes to the expansion of research on DI, particularly in learning Physics. It gives additional information on how such instructions can be implemented and the implications of their usage on the development of the practical capacity of students. Future researchers can build upon this to enhance knowledge in this area.

1.7 Delimitations

This study was delimited to investigating the effect of differentiated instructional strategies on the practical performance of Form 2 senior high school students in the simple pendulum experiment. The scope of the research was deliberately bounded by several factors to ensure focus and depth.

The study was conducted in two selected senior high schools within the Mampong Municipality and Sekyere Central District of Ghana. This geographical and institutional delimitation means that while the findings provide valuable insights, their generalizability to all senior high schools in other regions or cultural contexts may be limited.

The research focused exclusively on the topic of the simple pendulum, a core practical component in the physics curriculum. The study's participants were delimited to students who had previously been exposed to foundational physics theories and basic laboratory activities, ensuring they possessed the necessary background to engage with the intervention.

The assessment of outcomes was delimited to measuring students' conceptual understanding, practical skills, and attitudes towards physics, using a combination of pre-test/post-test instruments and structured questionnaires. The intervention itself was

confined to a specified period and utilized teaching methods specifically designed to be hands-on, learner-centered, and responsive to varied student readiness levels.

While these delimitations were essential to make the study manageable, they also define the boundaries within which the conclusions are most directly applicable.

1.8 Limitations of the Study

While this study offers valuable insights, several limitations should be acknowledged when interpreting its findings.

First, the generalizability of the results is constrained by the localized sample and restricted scope. The research was conducted in only two senior high schools within a specific geographical area in Ghana, focusing solely on Form 2 physics students. Consequently, the findings may not be fully representative of the broader population of senior high school students across different grades, regions, or educational contexts in the country.

Second, the temporal scope of the intervention presents a limitation. The study measured the effects of differentiated instruction (DI) over a specified, short-term period. While significant effects were observed, this design cannot capture the long-term retention of learning gains or the sustained impact of DI on student performance and attitudes.

Third, the reliance on specific research instruments introduces potential biases. The use of surveys and questionnaires, though methodologically sound, is subject to self-reporting biases, such as social desirability bias, where participants might provide responses they believe the researcher expects.

Fourth, despite efforts to control the research environment, the influence of extraneous variables could not be entirely eliminated. Factors such as students' prior knowledge, the inherent teaching style and enthusiasm of the instructors involved, and subtle differences in classroom dynamics and school resources may have inadvertently influenced the outcomes.

Finally, logistical and contextual constraints, including the availability of laboratory apparatus and adherence to fixed school schedules, may have affected the consistency and depth of the intervention's implementation across different student groups.

Despite these limitations, which highlight the complexities of conducting research in authentic educational settings, the study provides a robust foundation. These acknowledged constraints also help to identify productive avenues for future research, suggesting the need for longitudinal studies, more diverse samples, and investigations into other physics topics.

1.9 Organisation of the Study

This study was organised into five chapters. Chapter one provides background to the study, creates the problem statement, and creates the research questions and objectives. It also provides a description of the significance of the study, its limitations and delimitations, and provides the hypothesis and introduction to the study framework. The second chapter gives the literature review of the research topic. It has a theoretical background, conceptual framework, and empirical study of DI in the teaching of physics, that is, its impact on practical performance in the simple pendulum experiment. Research design, that is, population being studied, sample size, and sampling techniques, are explained in chapter three. It also explains instruments and data collection techniques, and data analysis techniques used.

Chapter four is where the findings of the study are given based on data obtained through pre-tests, post-tests, surveys, and interviews. The discussion compares these findings with the existing literature and responds to the research questions. Chapter five synthesises the study findings, concludes based on findings, and provides recommendations for practical application and future research in the education of physics. Chapter five also provides implications for policymakers and teachers to further promote DI for physics students.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

The purpose of the chapter is to provide a comprehensive review of literature related to the research topic. The literature review forms the foundation for an understanding of the theoretical, conceptual, and empirical foundations of the study, and also areas that the research attempts to address.

2.1 Theoretical Review

In this chapter, researcher discussed the principal theories that form the foundation of this research. Understanding these theoretical underpinnings is essential in order to grasp how DI can practically be applied in physics teaching. The emphasis is on key learning theories that are at the center of this research, guiding the trajectory towards understanding the role of DI in enhancing student performance in practical physics lessons.

2.1.1 Overview of Major Theories

The work in this research is grounded in two of the main theoretical frameworks: Constructivist Learning Theory and Vygotsky's Zone of Proximal Development (ZPD). These frameworks emphasise support, social interaction, and experiential learning as crucial variables for instruction. They reveal how particular instruction methods, such as DI, can enhance the results of learning significantly, especially for experiential physics exercises. These theories form a solid foundation for the development of instruction methods that are inclusive of various student needs. It is particularly so in Physics, where students are introduced to abstract and complex concepts. They point out the importance of

adjusting teaching methods based on the individual student's level of knowledge, one of the key principles of DI.

2.1.2 Constructivist Learning Theory

Constructivist Learning Theory, initially proposed by Jean Piaget and then further built by Jerome Bruner, establishes that learning is an active process of construction of knowledge by people from experiences and interactions. From this perspective, learning is an active process where people integrate new information with existing knowledge in order to build more profound insights into more advanced topics (Piaget, 1970; Bruner, 1966). Students are not passive recipients of facts but come to class with existing cognitive schemata which they use to interpret new information. This continuous link of new experience to existing knowledge is at the heart of deep and lasting learning.

Constructivism, as applied in this research, is the belief that different instructions can be applied, particularly in experiments such as the simple pendulum experiment in experimental physics. Physics is most often founded on abstract concepts such as motion, forces, and energy, which are often hard for the student to grasp. Constructivist theory hypothesises that experimental and practical exercises assist students in internalising these concepts better. Actively participating with the material, students accumulate their knowledge in a way that leads to more profound understanding than rote memorisation.

Differentiated instruction is also particularly appropriate for constructivism since it offers multiple ways students can access information based on what they know, how they prefer to learn, and their interests. In a physics laboratory, for instance, there will be students who easily understand theoretical principles, whereas others require additional support. Visual

aids, such as diagrams or animations, could clarify the connection between period and pendulum length for some students, but others can learn more about this from more abstract activities like predicting how changing variables will affect outcomes. Constructivism encourages this hands-on engagement, and it is thus an ideal framework for employing DI.

A constructivist practice during laboratory sessions may include students performing experiments involving hypothesis testing, and observing effects, for example, the measurement of a pendulum's period. More self-assured students may explore further what gravitational acceleration does to pendulum movement on various planets. In the meantime, those who require a little more help can concentrate on making easier observations, such as measuring how long it takes pendulums of different lengths to swing through a cycle. This way, everyone learns at their own rate, according to where they are at on their learning journey.

Vygotsky's Zone of Proximal Development (ZPD) plays a key role in shaping this research. The ZPD is a calculation of the difference between what one is capable of doing unaided and what one can accomplish while being directed by someone with greater ability, e.g., a teacher or peer. Vygotsky also highlighted the importance of social interaction in learning, arguing that students learn by being offered guidance or support to allow them to understand concepts that they could not otherwise acquire independently. For Vygotsky, learning was a collaborative exercise with association as a catalyst for intellectual development (Vygotsky, 1978).

In DI, Vygotsky's ZPD comes in handy. Differentiation is merely about providing the appropriate amount of support to learners at the level of understanding they are at in the present moment. For a physics practical lesson, for example, learners at varying levels of

readiness will need varying levels of support. Others will require instructions in stages as to how to set up the experiment, such as how to estimate the length of a pendulum or how to label its period. There are others who may require minimal support, needing less since they find the task easier. While the students gain more assurance and capability, the teacher increasingly withdraws the help so that they can become more independent learners. This scaffolding strategy helps students work within their ZPD, and as such, they accomplish more than they would have on their own.

Vygotsky's theory also points towards the need for peer collaboration in learning. Differentiated instruction in physics experimental work is possible by placing students with different skill levels together so that they may support one another. Gifted students can explain more complex concepts to other students, whereas weaker students can be responsible for arranging the experiment, learning from more skilled students. This cooperative approach not only propels students along their ZPD but also establishes a learning community in which knowledge is co-constructed.

Scaffolding within the ZPD may happen in several manners within a physics classroom tailored to student needs. Teachers may offer verbal cues, model correct usage of laboratory equipment, or ask questions that question students' higher-order thinking regarding the experiment. As students improve, the teacher gradually releases the distance, permitting independent problem-solving and critical thinking. This adaptive method ensures that each student is challenged and supported at the appropriate level, leading to more confidence and better understanding of physics concepts.

Vygotsky's theory validates the argument that instruction has to be adaptive to the learner's needs so that learners are supported as they grow academically. It also emphasises the

importance of social interaction, particularly peer support, as a core aspect of the learning process. Differentiated instruction inherently advocates for this adaptability through the process of negotiating learning experiences to each student's ZPD and promoting development through interactions with teachers and peers.

2.1.3 Relevance of Theories to the Study

Constructivist Theory of Learning and Vygotsky's Zone of Proximal Development (ZPD) are closely linked with the study's focus on the application of DI within physics practical classes. These theories provide very relevant information about the way students comprehend complex scientific concepts through active participation and social interaction.

Constructivism holds that the learners should be engaged via hands-on activities, real-life applications, and varied teaching strategies to facilitate them to gain an in-depth knowledge of physics. This is at the center of DI, which aims to meet the unique needs of all students in learning.

Vygotsky's ZPD places emphasis on scaffolding and peer-to-peer interaction, directing us to the need for teaching styles that stretch students in a suitable manner while offering them the support they need based on what they currently know. This clearly shows that teaching styles should adapt to learning levels with the aim of inducing growth and understanding.

These theories together provide the rationale for the use of DI in this study. Together, they warrant DI's design: Constructivism supports active, individualised learning, and ZPD governs scaffolding. For instance, DI's tiered assignments (e.g., mini-guides for low achievers, open-ended problems for advanced students) realise Vygotsky's scaffolding by manipulating support according to students' proximal development levels. They warrant the

use of varied teaching strategies, individual support, and specific instructional interventions to enhance students' engagement and performance in physics, especially in practical experiments like the simple pendulum. Such theories also frame the formulation of the study's methodology, ranging from the pre-test, post-test approach to the specific interventions employed for the experimental group.

2.2 Conceptual Review

This chapter sets up the key ideas at the forefront of the research, leveraging literature to argue and detail their applicability. Spanning such notions as DI, practical work in physics, and student performance, such background serves as the basis for understanding how these variables connect in senior high school physics education (Antwi et al., 2021).

Differentiated instruction has also been determined to make a worthwhile impact on the learning achievements of physics students in other contexts. Abamba et al. (2024) confirmed DI and blended learning enhanced achievement in physics and positively interacted with student cognitive styles. Toledo (2023) also found that instruction to multiple intelligences of students increased academic performance in Science 10 (Physics). In a different study reported that targeted learning strategies had significant comprehension gains where students' post-test scores were much higher compared to pre-test scores. Scaling up these findings to an African context, Ateko et al. (2025) discovered that both the 5E model and DI performed better than traditional teaching in thermal physics, highlighting the potential of learner-centered pedagogies to enhance students' understanding and motivation in physics lessons.

2.2.1 Definitions and Interpretations

a. Differentiated Instruction (DI)

Tomlinson (2001) defines DI as the act of adjusting teaching methods, materials, and assessments to address the diverse needs of students. Differentiation can take place along three dimensions: content (what they learn), process (how they are taught), and product (how they demonstrate what they learned). For instance, content differentiation is done through simplifying or enhancing teaching materials, process differentiation adjusts teaching methods to suit different learning styles, and product differentiation enables learners to express understanding using various products such as writing, oral presentation, or demonstration (Tomlinson, 2014; Corley, 2005). Other researchers, such as Santangelo and Tomlinson (2012), identify DI as a student-centered approach where there is continuous assessment and shifting grouping so that instruction remains responsive to the evolving learning needs of learners. This perspective emphasises the importance of continuous assessment in the ability to shape pedagogy around the variation of learners.

b. Physics Practical Work

Holmes and Wieman (2018) contend that physics practical works are an essential part of science education, as they provide opportunities for learners to connect abstract theories with real-world applications. Well-designed laboratory sessions allow students to observe physical phenomena, develop experimental competencies, and actively engage in scientific inquiry. Beyond reinforcing conceptual understanding, practical work fosters critical thinking and discourages rote memorisation by encouraging learners to reason through the principles under investigation.

Researchers agree that practical works emphasise theory, foster more conceptual understanding, and establish basic scientific thinking skills. For example, Empirical studies in Ghana show that physics practical works, including pendulum experiments, are particularly effective in enabling students to grasp abstract principles such as the relationship between the length of a pendulum and its period, as these hands-on activities allow them to directly observe and test the relationships themselves (Antwi et al., 2021).

c. Student Performance

Student performance generally refers to academic performance, which is measured by means of tests, examinations, and assessments. When learning physics, performance also refers to procedural skills like planning experiments, keeping data accurately, and interpreting results. Multiple factors influence the students' performance, including their prior knowledge, motivation, and the quality of instruction received (Buabeng et al., 2014). Various scholars hold that student performance represents both cognitive and practical skills. For example, Antwi et al. (2021) contend that in physics experiments, performance is not only measured by remembering theoretical aspects but also by the ability of students to perform experiments and analyse results.

2.2.2 Relevance of Key Concepts to the Study

Student performance is commonly interpreted to imply academic achievement, which in most cases is measured in terms of tests, examinations, and tests. Performance in physics also entails procedural skills such as designing experiments, recording appropriate notes on data, and interpreting results. The student's previous knowledge, motivation, and quality of instruction one receives are some of the many determinants of performance (Kidega & Zheng, 2024). Scholars agree that physics performance exhibits cognitive as well as

practical skills. For instance, Antwi et al. (2021) emphasised that in physics practical work, student performance is not only measured in terms of their memorisation of theoretical concepts but also in terms of their ability to conduct experiments and interpret results.

2.3 Empirical Review

Recent research still stresses the importance of individual students in physics education. For example, a Nigerian Ondo study indicated that the use of experiential teaching strategies enhanced physics retention as well as self-efficacy significantly more than conventional methods (Bada & Akinbobola, 2020). Similarly, in Nigeria's Delta State, DI combined with blended learning was shown to enhance physics achievement and interest for multiple cognitive styles, compared to lecturing (Abamba et al., 2024).

2.3.1 Studies on DI

Differentiated instruction, physics practical work, and student performance are the terms that constitute the foundation of which this study investigates the degree to which various teaching methods influence the ability of students to undertake physics practical exercises. Differentiated instruction provides a rigorous method to respond to the needs of various learners, providing an opportunity for all students (regardless of their starting point) to excel in physics practical work (Tomlinson, 2024; Corley, 2005). The study assumes that adjusting instructional approaches to meet the students' readiness level, preference, and interest will allow them to understand and apply physics concepts more effectively.

Physics practical works are extremely crucial as the topic has abstract concepts that are difficult for the students to grasp without practice sessions. This study is interested in how DI in an experiment like the simple pendulum, can enrich the understanding of fundamental

concepts such as motion, gravity, and oscillation. Hand-conducted experiments are well adapted to differentiation in the sense that they can allow for tasks that are uneven in difficulty, speed, and modes of engagement. For example, learners requiring additional guidance may be supported through structured scaffolding, whereas those demonstrating higher proficiency can be extended with independent inquiry tasks or more complex problem-solving activities (Toledo, 2023; Abamba et al., 2024).

Content differentiation in physics laboratories involves modifying materials and explanations to students' readiness levels, such as using visual simulations or simpler formulas for weaker students while presenting complex mathematics or longer experiments for better ones. Process differentiation involves modifying the instructional methods, such as group studies, individual research, or peer-tutoring. Product differentiation allows learners to show understanding through varied products, such as reports, presentations, or demonstrations (Santangelo & Tomlinson, 2012).

Student success in this study is not only memorisation of formulas but the application of knowledge in planning experiments, collecting data, and drawing reasonable conclusions. Evidence supports that DI enhances experiential skill and conceptual ability in science education (Smale-Jacobse et al., 2019). This study will compare students exposed to DI to those that have undergone traditional methods, noting differences in experimental skill, conceptual skill, and motivation.

The significance of the comparison is determining whether DI yields measurable gains in real-world physics outcomes compared to conventional teaching. The literature recognises that student science achievement is significantly based on instruction, motivation, and

learning resource access (Kidega & Zheng, 2024). Determining the role of DI in overcoming the determinants will improve effective pedagogy in senior high schools.

The findings of this study can be utilised to support teacher education, curriculum planning, and policy so that DI becomes an integral part of science teaching. Adjusting instruction to address the diverse needs of students, schools can create more supportive and inclusive classrooms that promote achievement and equity in physics teaching (Tomlinson, 2014; Corley, 2005; Smale-Jacobse et al., 2019).

2.3.2 Studies on Physics Practical Lessons

Differentiated instruction has been increasingly recognised as an effective framework for improving learning outcomes in science education, and particularly in physics practical work where students tend to struggle with abstract concepts. Salar and Turgut (2021) demonstrated that the integration of DI with the 5E learning cycle not only improved the physics attainment of students but also increased their self-efficacy, especially among low- and mid-achievers who tend to struggle with science courses. Their findings underscore the potential of adaptive instructional strategies in closing performance gaps. Similarly, Smale-Jacobse et al. (2019) claimed that DI confirms inclusivity through varied instructional strategies such as group work, peer tutoring, and mixed evaluations, thus more in-depth conceptual engagement throughout science courses.

Further studies have also proven the power of content differentiation in physics. Abamba et al. (2024) found that aligned instruction to students' level of readiness and cognitive styles (in DI) improved comprehension and physics achievement, with the students benefiting when tasks were aligned to the readiness level. Smale-Jacobse et al. (2019) also underscored

the importance of hands-on laboratory experiences in reinforcing theoretical knowledge, critical thinking, and problem-solving skills. They focused their study on how interactive materials such as simulations and technology-supported experiments add value to the practical sessions.

In the Ghanaian context, Kidega and Zheng (2024) demonstrated that addressing misconceptions with diagnostic pre-tests and intervention plans, like heuristic problem-solving approaches, enhanced student comprehension of motion, energy, and waves in physics. This concurs with international findings, for example, by Tomlinson (2014), who argued that DI allows teachers to align instruction strategies, content, and outcomes to students' readiness, interests, and learning profiles. Furthermore, Al-Shehri (2020) depicts that using DI in science classes does not only enhance academic achievement but also enhances critical thinking, which assumes that practical work and DI can provide arenas where hypothesis testing, observation, and application in real life is second nature.

Cumulatively, this body of work illustrates that DI, when applied in the setting of physics practical work, not only addresses diverse learning needs but also increases motivation, conceptual understanding, and laboratory performance. By scaffolding tasks, adjusting levels of difficulty, and offering multiple pathways to learning, DI supports more inclusive and effective science learning environments that can prepare students for ongoing study and professional engagement in STEM.

2.3.3 Comparative Studies: DI against Traditional Instruction

More and more comparative scholarship has compared DI with traditional approaches to teaching physics, with substantial differences in student engagement, understanding of

concepts, and skills acquisition being found by the authors. Traditional teaching (traditionally teacher-controlled with regularised pacing and normalised assessment) aims to deliver identical material to all students at once. While ideal for coverage of content, it does not address variability in learners' readiness, learning profile, and interest, particularly with inclusive classrooms (Tomlinson, 2017).

In contrast, DI is student-focused where content, process, product, and learning setting are adjusted to address individual need. Comparative researches have repeatedly reported that DI improves more self-motivated students, improved conceptual knowledge, and improved problem-solving (Santoso et al., 2025). Experimental research in which one group of students was taught using DI practices and another group with traditional methods all consistently register higher achievement gains for the DI group, particularly in science laboratory lessons.for example, demonstrated that an interactive-engagement approach in quantum physics lessons improved students' conceptual understanding and reduced gender achievement gaps compared to lecture-based teaching. Similarly, Smale-Jacobse et al. (2019) argued that DI's allowance for differential instructional pacing enabled weaker students to close gaps while extending knowledge for advanced learners.

Even with these benefits, the excellence of DI is relative. It is teacher competence, adequate preparation time, and instructional support that can be a make-or-break situation for it In situations where such as in Ghana, where classrooms are overcrowded and laboratories sparse remain the norm, complete implementation of DI may well be restricted. However even partial implementation—tiered assignments, flexible grouping, and multiple assessment modes, has been found to be more effective in teaching than purely traditional methods.

This dichotomy is particularly apparent in physics practical work. An experiment on a simple pendulum, for instance, can have general methods provide the same instructions and expected outcomes to all students. DI might, on the other hand, ask greater ability students to find formulae and do error analysis while providing scaffold support for lower ability students. This sort of targeted differentiation reinforces ideas at the same time building critical thinking, creativity, and scientific investigation skills.

2.3.4 Research Gaps

Though much has been written about DI, there are certain knowledge gaps in the research base. One of the greatest areas that are yet to be researched is the long-term impact of DI in practical subjects such as physics. Several studies report short-term gains in student performance, but the long-term effect of DI on problem-solving ability and critical thinking remains uncertain (Subban, 2006; Smale-Jacobse et al., 2019). Such higher-order skills are particularly crucial for physics, where students learn best through direct practical experience. Investigating whether DI contributes towards development of such skills in the long term would be useful to improve pedagogical practices.

Another gap is minimal research on how DI facilitates students to apply what they have learned independently outside the classroom or in higher-level academic environments. More research has to be conducted to determine the effect of this approach on students' ability for self-directed learning and scientific inquiry, as well as those skills required for lifelong problem-solving (Tomlinson, 2017).

Another shortcoming in the existing literature is that there are few studies on the impact of DI in low-resource countries and across socio-economic levels. Most of those that have

been conducted were in schools with relatively good laboratory equipment and instructional materials, which allow for easy implementation of differentiation (Smale-Jacobse et al., 2019). In contrast, the majority of Ghanaian schools, and indeed most schools in Africa, have sub-standard infrastructure and limited resources, with the question of how DI can be adapted to function in low-resource settings (Akyeampong, 2017). Examining ways in which DI is integrated with culturally responsive pedagogy of teaching and extemporised laboratory procedures can be useful in determining how teachers can sustain differentiation in the absence of adequate resources. Closing these gaps is of the utmost significance to maximise DI especially in heterogeneous classrooms and socio-economically disadvantaged areas. Longitudinal studies of its long-term impact, as well as studies focused on socio-economically heterogeneous settings, would allow teachers to design more equitable and effective strategies. This would ensure that DI meets the needs of all students regardless of their background or resources.

2.4 Conceptual Framework

2.4.1 Development of the Conceptual Framework

Theoretical underpinning of this research is based on studies of DI, physics practical classes, and student performance. All studies conclude that employing DI practices, in line with students' needs differentiated, has a significant effect on their motivation and achievement. This holds particularly true for subjects like physics, in which theories are to be integrated with experimental laboratory skills (Tomlinson, 2017; Dounas-Frazer & Lewandowski, 2018). It is assumed that modifying teaching dimensions such as content, process of learning, and final product equals improved student performance, especially in experimental settings such as an experiment involving a simple pendulum. Moreover,

teaching strategies, independent variables, independently affect student performance, the dependent variable, in physics laboratory classes, with student preparedness and interest being key intervening variables (Santoso et al., 2025). Figure 2.1: below shows conceptual framework of DI.

The Influence of DI on Student Learning Outcomes

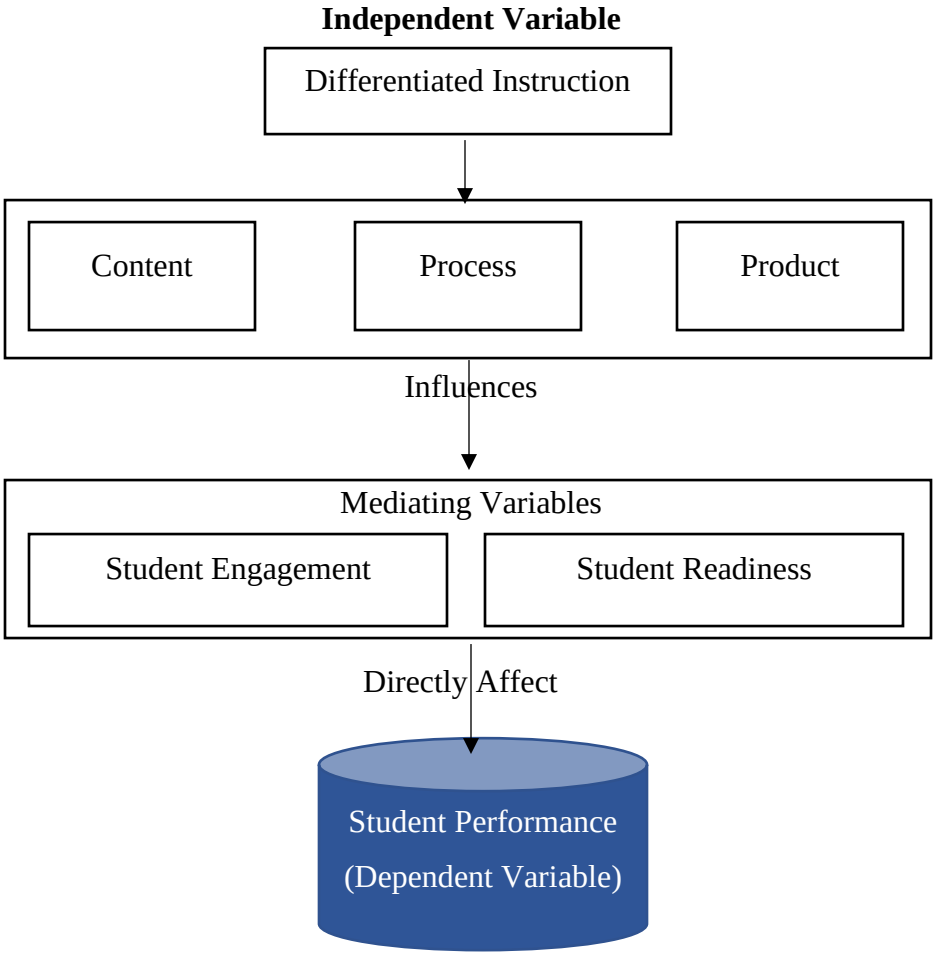

Figure 2.1: Conceptual framework of DI (Tomlinson (2001) and Vygotsky (1978).

2.4.2 Explanation of Variables

Conceptual model illustrates the connection between DI, student engagement, and physics classroom performance. As illustrated in Figure 2.1, the model speculates that DI directly impacts engagement (mediator) through content, process, and product modifications.

Engagement, conversely, enhances practical performance (dependent variable). For example, visual aids (content) can increase engagement among visual learners, thereby promoting graph-plotting ability, while flexible grouping (process) enhances participation and conceptual understanding.

Differentiation of content involves aligning instructional materials with students' levels of readiness (e.g., simplified field equations for lower-performing students, detailed derivations for higher-performing students). Differentiation of process involves the application of different instructional strategies, such as placing kinesthetic learners in hands-on pendulum models or auditory learners in discussion-based analysis. Product differentiation enables students to demonstrate competency in varying ways, including laboratory reports, oral presentations, or re-experiments. Together, these accommodations construct engagement (measured in terms of participation rates, persistence, and self-reported interest) that mediates functional gains in performance, such as accurate period calculations and improved measurement proficiency.

This model aligns with Vygotsky's (1978) theory of the Zone of Proximal Development (ZPD), in which scaffolding using DI strategies closes learners' potential and what they currently know. Similarly, it also resonates with constructivist beliefs, which assume that learning is optimally achieved when students are engaged actively constructing knowledge through experience and individualised activities (Piaget, 1970). In contemporary terms, DI provides the framework for such implementation of constructivist and socio-cultural tenets within physics classrooms, thus upgrading engagement as well as performance (Tomlinson, 2001; Smale-Jacobse et al., 2019).

2.5 Historical Context

The introduction of DI in science education reflects the global trend towards shifting from teacher-centered to learner-centered pedagogy. DI aligns with existing education reforms such as the National Teachers' Standards (NTS) and the National Pre-Tertiary Education Curriculum Framework (NPTCF), both instituted in 2017, that accord significance to learner-centered practices as central to improving science teaching outcomes. Nevertheless, physics instruction in most Ghanaian senior high schools continues to remain teacher-centered due to infrastructural constraint, shortage of laboratory equipment, and insufficient teacher preparation, which creates a gap in implementation between policy design and classroom practice (Akyeampong, 2017). The study aims to find out how DI can bridge such gaps in implementation as well as address persistent issues in teaching physics.

Physical education in Ghana has historically been lecture-heavy with minimal responsiveness to diverse student needs (Buabeng et al., 2014). Such teacher-centered colonial legacy persists despite widespread acknowledgment of its limitations in facilitating inquiry and hands-on science learning (Bada & Akinbobola, 2020). The policy experimentation of the application of the principles of DI via reforms like the Standards-Based Curriculum (SBC) initiated in 2019 is reflective of the nation's attempt at policy reform; however, classroom practice has typically lagged behind policy intent (Anamuah-Mensah, 2020).

Over time, teachers realised the need to deviate from traditional methods, and DI saved the day by requiring diversified instructional practices that account for the various learning speeds and styles of learners. In experimental physics, this revolution promotes experiential

and individualised learning grounded on learners' readiness and ability (Dounas-Frazer & Lewandowski, 2018).

The application of DI in physics laboratory activity has enabled students with varied levels of comprehension to completely participate in experiments. Teachers can grade tasks at different levels of difficulty, use varied types of assessment, and embrace varied pedagogical methodologies (such as group work, peer tutoring, or visual aids) to serve the needs of learners. The varied methods have been very effective in teaching challenging concepts of physics, such as motion and energy (Buabeng et al., 2014).

2.5.1 Challenges in Implementing DI

Because of its clear benefits, DI is however hampered by a range of barriers to its implementation in physics, particularly in low-resource settings. The most stringent of these is the lack of lab equipment and experimental materials. Studies in Ghana have shown that schools lack basic physics equipment such as pendulums, measuring instruments, and power supplies, which restrict practice possibilities and reduce the impact of DI (Kidega & Zheng, 2024; Antwi et al., 2021).

High student-teacher ratios are another long-standing problem, particularly in the developing world. Crowded classrooms impede one-to-one attention and DI to address diverse learning requirements. Akore, Afutor et al. (2023) observed that large class sizes in Ghanaian pre-tertiary schools constrain teachers’ ability to offer close monitoring and formative feedback, making the effective implementation of DI particularly challenging. Without proper feedback and guidance, learners cannot harness the strengths of experiential, differentiated physics lessons.

Teacher training is also a critical barrier. Few instructors are adequately trained to deliver DI in the laboratory. Studies show that teachers may understand DI theoretically but lack the pedagogical content knowledge and practical skills that enable them to develop tiered assignments, modify learning materials, or apply assessment data to determine instruction. They, therefore, use teacher-directed approaches, especially in physics when time pressure to complete a packed syllabus within limited class time is imperative (Tomlinson, 2017; Akore et al., 2023).

Time pressures compound the challenge. Physics practical lessons take a long time to prepare, carry out, and assess. Creating differentiated resources, classifying students by ability, and offering individualised feedback can prove difficult within finite lesson times. To survive, a lot of teachers fall back on "one-size-fits-all" approaches, which erodes motivation and decreases learners' achievement potential (Smale-Jacobse et al., 2019).

Curriculum rigidity also constrains DI. Syllabuses and testing frameworks in the majority of education frameworks concentrate on standardised content presentation and uniform tests with minimal space for student-centered or individualised instruction Akore et al. (2023). Curriculum rigidity suppresses teachers' capacity to modify instruction to suit learners' readiness, pace, and interest.

Finally, cultural norms pose an obstacle. In the majority of African classrooms, the dominant instructional culture remains teacher-centered, and the teacher is regarded as the sole source of knowledge and authority. This conventional thinking is contradictory to the collaborative, student-centered design of DI and, in the majority of cases, leads to resistance or implementation issues (Santangelo & Tomlinson, 2012).

2.6 Summary

This chapter explained the conceptual, empirical, and theoretical foundations related to DI, physics practical work, and student achievement. Theoretical foundations such as Constructivist Learning Theory (Piaget, 197) and Vygotsky's Zone of Proximal Development (ZPD) help to establish the knowledge of how DI increases student learning outcomes. Vygotsky's ZPD, for instance, deals with the idea of guided learning and scaffolding, which are both closely related to the idea of DI (Vygotsky, 1978).

Empirical studies from 2015 to 2024 show that DI has a positive effect on the performance and attitude of students in physics even when there are challenges like limited resources and class size. For instance, Antwi et al. (2021) confirmed that differentiated strategies improved Ghanaian students' acquisition of scientific process skills in physics practical work. In the same line, Abamba et al. (2022) stated that instruction differentiated, along with blended learning and other methods, improved Nigerian physics learners' performance with varied cognitive styles. Recent research also points out that DI, on adoption in science lessons, supports learning and deeper conceptualisation even in resource-poor environments (Doucette et al., 2024).

Literature review also indicated areas of gaps, particularly on the application of DI to senior high school practical physics teaching. Those gaps are the foundation of the next chapter, which captures the research methodology used in investigating the impact of DI on the performance of students during physics practical work.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter describes the way in which the study was conducted. It addresses the study area, philosophical underpinning, research design, sampling technique, study population, sample size, data collection instrument, data collection procedure, data analysis and ethical consideration.

3.1 Research Paradigm

This study is grounded in a combined paradigm of constructivism and pragmatism, reflecting both the process of knowledge construction and the practical usefulness of instructional strategies. Constructivism, as advanced by Piaget (1970) and Vygotsky (1978), posits that learners actively construct meaning through prior knowledge, personal experience, and social interaction. This perspective supports the use of differentiated instruction (DI), which prioritises student-centred learning, hands-on activities, and collaborative engagement. In physics education—particularly in practical investigations such as the simple pendulum experiment—constructivism aligns strongly with the view that students learn best when they manipulate materials, explore relationships, and co-construct understanding with peers. Pragmatism, endorsed by Dewey (1938), complements this by emphasising practical consequences, problem-solving, and educational actions that produce measurable improvements. From a pragmatic standpoint, the value of DI lies in its capacity to generate tangible learning gains in real classrooms, especially within resource-limited Ghanaian senior high schools. Together, these paradigms provide a philosophical

justification for investigating not only *how* DI supports the construction of knowledge (constructivism), but also *whether* it leads to meaningful, observable improvements in physics learning outcomes (pragmatism). This dual foundation ensures that the study examines both the theoretical and practical merits of DI within authentic school settings.

3.2 Research Approach

Guided by the combined constructivist–pragmatist paradigm, the study adopts a quantitative research approach. This choice reflects the pragmatic commitment to evaluating the effectiveness of differentiated instruction through measurable outcomes and empirical evidence. While constructivist principles inform the nature of the instructional intervention (promoting student engagement, exploration, and active meaning-making) the pragmatic orientation requires systematic assessment of the impact of DI on students' physics performance. Consequently, the study relies on numerical data derived from pre-test and post-test scores, enabling objective comparisons between experimental and control groups. The use of intact classes and random assignment at the class level further aligns with quantitative traditions, allowing for statistical analysis to determine whether DI produces significant gains in conceptual understanding and practical competence. In this way, the research approach operationalises the philosophical stance by combining constructivist-informed pedagogy with pragmatic, outcome-focused evaluation.

3.2 Study Area

The research was conducted in Mampong-Municipality and Sekyere Central senior high schools (Figure 3.1). There are eight government senior high schools in the two study

locations. The Mampong Municipal is one of the 261 Metropolitan, Municipal and District Assemblies (MMDAs) of Ghana and consists of one of the 43 of MMDAs of the Ashanti Region whose administrative capital is Mampong. It is bounded by longitudes 00 05W and 10 30W and latitudes 60 55N and 7 0 30N and is a total area of about 23.9 km^2. The population of the Municipality according to the 2021 Population and Housing Census, is 116,632 consisting of 56,965 males and 59,667 females. Sekyere Central District is one of the 261 Metropolitan, Municipal and District Assemblies (MMDAs) in the Ghanaian state, and among the 43 MMDAs in the Ashanti Region and has its capital as Nsuta for administrative purposes.

The District is located in the north of the country and has a land surface area of 1,631.1 sq. km. It lies between longitudes 0.05 and 1.30 west and latitudes 6.55 and 7.30 north. The District has a population from the 2021 Population and Housing Census of 73,228 comprising of 36,490 males and 36,738 females (Ghana Statistical Service, GSS, 2021 PHC). Figure 3.1 below is the Map of Mampong Municipality and Sekyere Central (Nsuta).

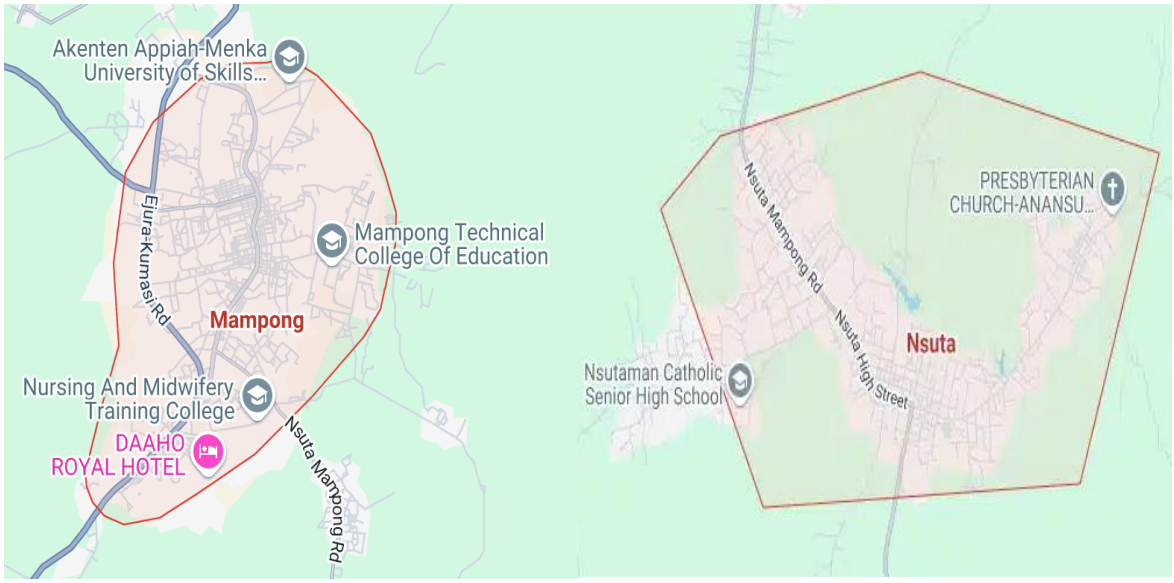

Figure 3.1: *Map of Mampong Municipality and Sekyere Central (Nsuta)*

Source: Ghana Statistical Service (2021)

3.3 Research Design

Quasi-experimental design was adopted in this study, specifically the pre-test–post-test control group design. The design is appropriate for determining the effect of DI on the applied performance of senior high school students in physics in their natural classroom setting, where randomisation of subjects is typically not feasible (Creswell & Creswell, 2018). The research utilised two groups: one control group that received instruction through normal teaching methodologies and one experimental group that was taught through DI.

Both groups were administered a pre-test at the beginning of the study to establish their baseline experimental ability and knowledge in this case on the simple pendulum experiment. They were later administered a post-test following the instruction period to measure changes in experimental skill and conceptual understanding of physics by the students. The difference between the pre-test and post-test scores enabled the study to establish the effectiveness of DI.

This design was selected because it permits a systematic examination of the effect of DI within intact classroom settings, thereby enhancing the study's external validity (Creswell & Creswell, 2018). In addition, the inclusion of a control group strengthens the design by demonstrating the extent to which changes in student performance noted can be attributed to the instructional strategy itself (Fraenkel et al., 2019).

3.4 Population

The study focused on senior high school pupils taking elective physics in schools within the Mampong Municipality and Sekyere Central of Ghana's Ashanti Region. The

population of interest was all Form 2 students taking elective physics, as they had already been introduced to basic physics concepts as well as laboratory practical work. This was chosen as they already possess previous experience and know-how of hands-on experiments like the simple pendulum, therefore appropriate for assessment of the impacts of DI on their laboratory skills in physics.

The total target population was 318 Form 2 physics students of St. Joseph Senior High School and Ghana Muslim Mission Senior High School. They were selected purposefully due to their easy accessibility, minimal laboratory facilities, and consent to allow the study to be conducted.

3.5 Sampling and Sampling Techniques

The study utilised a purposive sampling method in selecting two senior high schools. The schools were picked based on the question of whether or not they had adequate physics laboratories and viable physics departments that could effectively adopt practice lessons such as the simple pendulum experiment. Table 3.1 presents the sample for the study.

Table 3.1: Sample Size Distribution

No.	School	Physics Students	Participants
1	Ghana Muslim Mission Senior High School	Science A =40 (Expt) Science B =39 (Ctrl)	79
2	St. Joseph Senior High School	Science A=40 (Expt)) Science B=41 (Ctrl)	81
	Total		160

Table 3.1 displays the distribution of the study's sample size, which consists of the number of physics students from two senior high schools. Each school contributed two intact science classes, one of which served as the experimental group while the other was the

control group. At Ghana Muslim Mission Senior High School, a total of seventy-nine (79) physics students were grouped by the school into Science A (40 students) and Science B (39 students). Science A was randomly selected to serve as the experimental group, where personalised differentiated instruction was provided according to students' learning needs, while Science B functioned as the control group and received the usual instructional approach.

In the same way, St. Joseph Senior High School had eighty-one (81) physics students distributed into Science A (40 students) and Science B (41 students). Here, Science A was randomly assigned to receive normal instruction, whereas Science B was designated as the experimental group based on their pre-test performance and taught using differentiated instruction.

Summing up the two schools, the experimental group consisted of 79 students (40 from Ghana Muslim Mission SHS and 39 from St. Joseph SHS), while the control group consisted of 81 students (39 from Ghana Muslim Mission SHS and 42 from St. Joseph SHS). This fairly balanced distribution gave each school an experimental group and a control group, and thereby allowed for an unbiased and fair comparison of the two approaches to teaching physics practical performance.

3.6 Data Collection Techniques

In this study, the data were gathered through the use of pre-test and post-test evaluation and standard questionnaire. These were specifically designed for data gathering for attaining the research objectives such that measurement on how DI impacts students' achievement in the simple pendulum experiment is extensive.

3.6.1 Pre-test and Post-test

Two equivalent parallel tests were developed: PPPTa (for pre-test) and PPPTb (for post-test). Pre-test was administered before applying DI to establish the baseline level of knowledge and understanding of the students in the simple pendulum experiment. It measured their ability to grasp theoretical concepts as well as apply them practically to carry out the experiment. The pre-test had 12 items: ten objective multiple-choice questions and two practical activities with short-answer questions. Multiple-choice questions were to be set on the significant theoretical concepts of the simple pendulum, such as its time period, factors that affect its period, how to measure it correctly, and interpretation of data. The practical aspect consisted of students making a simple pendulum of two varying lengths, measuring oscillation times, and filling in short structured questions on experimental safety measures and factors that affect the pendulum.

There was a post-test with the same students after the teaching intervention. The post-test included 10 items: eight short-answer questions on theory comprehension and practical procedures, and two structured practical tasks. Similar to the pre-test, the post-test required students to design a pendulum experiment, take timings, and write short-answer responses about errors to avoid, good experimental procedure, and factors contributing to simple harmonic motion. The post-test was used to measure students' learning and acquisition of knowledge and skills on a straight comparison basis with the pre-test score. From this, any measurable improvement resulting from differential instruction could be determined. The questions for the pre-test and post-test were analogous but equivalent and spanned analogous content with the same levels of difficulty (see appendix I, for pre-test and post-test instrument).

3.6.2 Structured Questionnaire

To complement the research, a guided questionnaire was prepared and utilised as part of the key tools utilised in collecting information from the students. The guided questionnaire was mostly intended to ascertain the learning needs of students, issues they encounter in carrying out simple pendulum experiments, attitudes towards applying DI strategies in physics class and DI in physics laboratory. The items were stated in simple, straightforward language to enable the students to answer honestly and effortlessly.

The survey was divided into four sections that comprised a total of forty-five (45) questions. Section one, *Background Information*, had only two questions that inquired about students' age group and gender. This preliminary information enabled the researcher to remain informed of the background of responses.

The second section, *Learning Needs and Challenges in Simple Pendulum Experiments,* had fifteen (15) questions. The questions asked how well the students understand key concepts, what is difficult for them about the experiment, how much help they need on average, and what learning resources they find most useful. The majority of this section's questions were multiple choice, where the students selected the best description of their experience. This section of the survey was given to the control and treatment groups before the instructional intervention in trying to get baseline scores on what the students already knew and were struggling with.

The third section, *Differentiated Instructional Strategies,* contained fifteen (15) items. They were rated on a four-point Likert scale ranging from *Strongly Disagree* to *Strongly Agree*. This section was all about whether or not the students held the belief that the different instructional methods (like dividing lessons into pieces, mixed levels of difficulty, increased

learning material, and an option in assignment) aided in learning. This exercise was carried out post-intervention, so students could give an opinion regarding how the teaching methods had influenced their learning.

The fourth part, *Attitudes Toward DI in the Physics Laboratory*, had fifteen (15) items employing an identical Likert scale. It probed whether students felt DI was better able to explain physics concepts and explain them more clearly. This part also was administered post-intervention to see whether there was any change of attitude amongst students after they had been introduced to DI.

The survey utilised mainly close-ended questions in an effort to provide ease of analysis of the responses as well as comparison of findings among the different groups. Including factual background questions, multiple-choice questions, and scaled questions, the survey collected a mix of information about the problem of the students, their preference, and attitudes. This was necessary in establishing the effect of differentiated instructional strategies on the performance and ability of students to conduct the simple pendulum (see Appendix I, pg. 110).

3.7 Pre-Testing, Validity and Reliability of the Instruments

The instruments were shown to supervisors for face, content and construct validity verification. Pre-testing was carried out by using 30 Form Two physics students of Nsutaman Senior High School to give research instrument clarity, appropriateness and psychometric quality. Results indicated high reliability of the instrument, with Cronbach's alpha ($\alpha = 0.943$) indicating high internal consistency of the questionnaire. Feedback from participants also informed question wording and presentation adjustments before the

primary study. The results of the reliability tests are shown below in Table 3.2 (see appendix II for validity output).

Table 3.2: Internal Consistency for Part 1, 2 and 3 of the Questionnaire

Reliability Statistics	
Cronbach's Alpha	N of Items
.943	45

Similarly, the multiple-choice section of pre-test also yielded Cronbach's alpha of 0.739, and Cohen's kappa ($\kappa = 0.847$) with almost perfect inter-rater reliability for essay items. Student answers were double-marked independently by two trained markers on the essay item. For establishing consistency between the two sets of scores, Cohen's Kappa coefficient was utilised as an inter-rater reliability measure. According to Kottner et al. (2011), the values of Kappa are interpreted against the following: values ≤ 0 no agreement, values 0.01 to 0.20 fair agreement, 0.21 to 0.40 slight agreement, 0.41 to 0.60 moderate agreement, 0.61 to 0.80 substantial agreement, and 0.81 to 1.00 almost perfect agreement. In this research, the computed Kappa coefficient, from the table which was presented in Table 3.3, was 0.847. Based on the model of interpretation of Kottner et al. (2011), this indicates a very high (nearly perfect) level of agreement between the two scorers, and therefore the reliability of the score for the essay items (see Appendix II, for the validity output).

Table 3.3: Internal Consistency for Pre-Test multiple choice section and Inter – Rater Reliability for Essay Section

Reliability Statistics	Value	N of Items/Valid Cases
Cronbach's Alpha	.739	10
Measure of Agreement (Kappa)	.847	20

As shown in Table 3.3, the multiple choice's high reliabilities and inter – rater reliability of the essay component were an assurance that the instruments were valid to collect authentic data about students' on-the-job performance and attitudes. The instruments were later revised following pilot testing to incorporate any modifications required such as rewording unclear items and making questions more clearly grounded on the research focus. These activities enhanced the instrument's coherence, clarity, and reliability to be used in the main study. Therefore, it can be argued that the score of the instrument was good enough for the instrument to be used in the main study.

3.8 Data Collection Procedure

Data collection for the research was organised systematically to attain the information gathered on the impact of DI on senior high school students' performance in physics practical work, the simple pendulum experiment. This was done in stages with the experimental and control groups of senior high school students as the target population.

3.8.1 Phase 1: Pre-Test Administration

The first phase of data collection was when both the experimental and control groups were given the pre-test (PPPTa). The pre-test was administered in an attempt to gauge the existing knowledge and capability of the students on the simple pendulum experiment. Both control and experimental group students received identical pre-test, comprising multiple-choice questions and experiments to measure knowledge of the theory and competence to conduct the experiment. Under the observation of the researcher, the test was supervised to provide equal test conditions.

3.8.2 Phase 2: Implementation of DI

In the second phase, DI strategies were implemented during regular class sessions, based directly on the pre-test results and the learning needs identified. The intervention was conducted for four weeks, a total of six lessons, with each lesson taking 60 minutes.

Based on the pre-test scores, all the experimental classes in the schools were stratified into three subgroups according to their readiness levels: 26 low achievers who need basic support, 48 with medium comprehension, and 6 high achievers who are more advanced students. The grouping allowed each student to be taught at a level that matched their Zone of Proximal Development (ZPD), helping them work toward the same overall learning goals. To operationalise the tiered approach:

- Low achievers employed step-by-step guides and peer mentoring to help consolidate their basic skills and apparatus handling confidence.
- Moderate achievers employed guided inquiry tasks with frameworked teacher feedback to consolidate their understanding.
- High achievers employed independent hypothesis testing, higher-level calculations, and more advanced data analysis (see pg. 60-61 for complete lesson plans).

Throughout the intervention, three big differentiation strategies combined with a mixture of 15 different specific differentiation instructional strategies (*see Appendix I for questionnaire part 3*) guided the teaching of the lessons. The three big differentiation strategies are:

- **Content Differentiation:** Tasks were adjusted to the level of each subgroup. Foundational students worked on simplified instructions and scaffolded exercises, while

advanced students did extend problem-solving, such as deriving relevant equations and analysing complex results. Below this were the following specific DI approach used.

i. Learning from textbooks, videos, and diagrams simplifies the learning of physics theory.
ii. Real-life examples simplify the physics content.
iii. Access to extra notes, summaries, or simplified explanations helps in learning difficult concepts.
iv. Learn physics better if theory and practical experiments are combined in classes.
v. Clear step-by-step instructions for experiments makes the physics content easier to understand.

- **Process Differentiation:** Lessons incorporated a mix of visual aids, hands-on experience, and interactive discussions. For example, students with high tactile learning preferences spent more time manipulating the pendulum equipment, while visual learners used diagrams, charts, and simulations to facilitate understanding. Under this fell the following specific DI strategy used.

i. Learning in pairs or small groups makes physics experiments more understandable.
ii. Experiments conducted using various instruments or materials aid in comprehending the same idea more effectively.
iii. Receiving additional time or practice to conduct an experiment again aids in learning.
iv. Conducting demonstrations or simulations assists in grasping how experiments are done.
v. Performing brief activities in stages rather than continuously helps in conducting experiments more effectively.

- **Product Differentiation:** Students represented their learning in ways that worked best for their strengths, such as individual reports, group presentations, or live practical demonstrations. Under this were the following specific DI strategies used.
    i. Having options like written reports, oral presentations, or practical demonstrations, helps in showing what I know.
    ii. Prefer to show understanding through experiments rather than written work alone.
    iii. Being able to choose the type of assignment (project, test, experiment), helps in doing best work.
    iv. It makes me feel safer in physics class having adaptable ways of being assessed.
    v. Expressing work in different forms (posters, videos, practical models), helps in communicating what I've discovered in physics.

Lessons for addressing the major areas of the simple pendulum experiment - learning theory, setting and obtaining the apparatus correctly, recording and analysing data, and plotting and interpreting graphs - were organised in weekly blocks. In each session, students were not taught in mixed-ability groups. Rather, they were put in small groups or assigned tasks based on their level of learning. This open framework allowed the teacher to differ the depth and speed of teaching so that students who needed more guidance received more guidance, and students who were prepared for more advanced activities were appropriately challenged.

A week's lesson incorporated practical work, short theory reminders, and group discussion so as to combine hands-on experience with reflection and learning from others. The structure enabled the incorporation of the differentiated activities within the regular school schedule without disruption.

For comparison, the control group received the same introductory pendulum material but through traditional, whole-class teaching with no ability grouping or differentiated activities.

Detailed lesson plans for every session, together with subgroup objectives for every session, are presented in Table 3.5. Each week's class combined practical activity, short theory reminders, and group discussion to balance hands-on experience with reflection and learning from each other. This format enabled the accommodation of the differentiated activities within the school's normal timetable without its interruption.

By contrast, the control group was presented with the same simple pendulum content but through traditional, whole-class teaching with no ability grouping or differentiated activities. Detailed lesson plans for each session, together with subgroup objectives for each, are presented in Table 3.5.

Table 3.5: Content of Lesson Notes Prepared for Each Lesson.

DI – Phase 2: Implementation (Strand 3.11.2 – Simple Pendulum)

Week	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 laboratory 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	Measureme-nt 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 laboratory 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 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	Laboratory report Observation check list Concept map	String Retort stands Meter rules

Table 3.5. continued

Week	Lesson Title	Content Standards	Indicators & Objectives	Teaching & Learning Activities (Differentiated)	Assessment Strategies	Resources/ Materials
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

3.9.3 Phase 3: Post-Test Administration

When the instructional period had been completed, both the experimental and control groups were administered the post-test (PPPTb) to determine the effect of DI on students' performance. The post-test (PPPTb) contained the same types of items and hands-on activities as the pre-test (PPPTa), with equivalent content and difficulty levels to allow a direct comparison of students' performance before and after the intervention. The experiments were carried out under the same conditions as the pre-test to ensure consistency in data. Additionally, Parts C and D of the questionnaire were administered only to the experimental group, as they focused on students' experiences and attitudes regarding the differentiated instruction strategies used during the intervention.

3.10 Data Analysis

Control and experimental group data were processed carefully to ensure confidentiality and accuracy. Quantitative pre-test, post-test, and questionnaire data were first obtained by collecting students' completed instruments immediately after administration. All questionnaire responses (both multiple-choice and Likert-scale items) were checked for completeness and then prepared for entry. The data were entered into SPSS version 23, with each student assigned a unique identifier to maintain anonymity and to allow comparison between their pre-test and post-test scores. Responses on fixed questionnaires (Likert-scale items) were coded numerically for analysis (1 = "Strongly Disagree", 2 = "Disagree", 3 = "Agree", 4 = "Strongly Agree").

Following data entry, full verification was conducted to identify inconsistent or missing entries. Incomplete responses were corrected where possible by cross-checking with the

original questionnaires, while invalid or unusable entries were excluded to maintain a clean dataset. All hard-copy data, questionnaires, and test papers were stored securely in a locked cabinet, and electronic data were saved in encrypted, password-protected files. Regular backups were made to prevent any loss of data.

Research questions were answered and hypothesis were tested using the corresponding statistical methods to yield valid and reliable results. Research questions and hypotheses are stated below with the corresponding statistical methods utilised:

1. **Research Question 1**: *What are the varying learning needs of senior high school students studying physics when conducting a simple pendulum experiment?*

   Descriptive statistics such as frequencies and percentages were used to portray the learning needs of students.

2. Research Question 2: *What specific differentiated instructional strategies are most influential in improving senior high school physics practical performance in the simple pendulum experiment?*

A descriptive statistic (percentages, frequencies) and regression analysis were used to investigate the ways in which various differentiated instructional strategies predicted student performance in the simple pendulum experiment.

3. Research Question 3: *What are students' attitudes towards DI in the physics laboratory environment?*

Data collected from the questionnaire were analysed with descriptive statistics (mean scores, percentages, frequencies) in order to discuss attitudes of students towards DI in physics laboratory. In interpretation, mean scores greater than 2.50 were classified into

showing a positive attitude, while mean scores of 2.50 and below were classified into showing a negative attitude.

4. Hypothesis: *There is no statistically significant difference between the senior high school physics students who were provided with DI and those provided with traditional instruction in conducting the simple pendulum experiment.*

Pre-test scores of experimental and control groups were verified for normality using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Since the data violated the assumptions of the parametric test, the Mann–Whitney U test was used to compare both the pre-test and post-test scores.

3.11 Ethical Considerations

Ethical considerations were managed with caution during the study according to established research guidelines. Informed written consent was obtained from all those involved in the research (students), parents/guardians, and school officials prior to the data collection. The intent, procedures, risks, and advantages of the research were described clearly in language appropriate for the age to ensure complete understanding. Participation was completely voluntary, and rights were clearly reserved to withdraw at any time without suffering any academic penalty.

In order to preserve confidentiality, all the identifiable data were anonymised using alphanumeric coding (e.g., Expt-E01 for the experimental group, Ctrl-C01 for the control group). Data were stored securely in password-protected files, with physical records kept in locked cabinets accessible only to the research team. Following data collection, participants were debriefed about the study results and implications. To uphold equity

standards, control group instructors were subjected to DI training after the study to make sure that everyone benefited from the intervention.

3.12 Summary

This chapter presented the research design used to examine the impact of DI on the laboratory performance of senior high school students of physics in the experiment of a simple pendulum. The research was a quasi-experimental design type using pre-test and post-test for an experimental group (treated with DI) and control group (normal instruction). It was conducted in two senior high schools within Ghana's Mampong enclave, among a purposive sample of 160 Form 2 physics students.

Collection of data was through pre-tests, post-tests and questionnaire. Ethical practices, including informed consent and anonymity of data, were adhered to rigidly.

Intervention included leveled DI strategies (content, process, and product differentiation) in relation to students' readiness levels (low, medium, and high achievers). Descriptive statistics, independent-samples t-tests, and multiple linear regression were applied to analyze data in determining the effect of DI on practical performance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter provides the research results of the effect of DI on experimental performance of senior high school students in the simple pendulum experiment. It hierarchically analyses data collected from pre-tests, post-tests, and guided questionnaires and contrasts outcomes between the experimental group (with DI) and the control group (normal instruction).

4.1 Results

Research Question 1: *What are the various learning needs of senior high school physics learners in a simple pendulum experiment?*

Table 4.1 indicates the responses of the students to their learning needs and the specific challenges they faced while conducting the simple pendulum experiment. The results indicate that, although a minority of students were well-informed and confident, the majority demonstrated significant knowledge gaps and limited laboratory skills. Questionnaire Part B was specifically used to gather this information, as it focused on identifying students' perceived learning needs and the difficulties they encountered during the experiment.

Table 4.1 Results of Students' responses to questions on their learning needs and specific challenges related to the simple pendulum experiment (N = 160).

Items	Response Option	Frequency (f)	Percentage (%)
1. Do you understand the relationship between pendulum length and period?	Yes, completely	34	21.3
	Somewhat	45	28.1
	Slightly	44	27.5
	Not at all	37	23.1
2. Which areas of the pendulum experiment do you find challenging?	Measuring length	37	23.1
	Recording time	46	28.8
	Calculating period	38	23.8
	Graphing results	39	24.4
3. Understanding of simple harmonic motion.	Very well	34	21.1
	Fairly well	40	25.0
	Poorly	45	28.1
	Not at all	41	25.6
4. Helpfulness of written instructions.	Extremely helpful	36	22.5
	Somewhat helpful	40	25.0
	Slightly helpful	45	28.1
	Not helpful	39	24.4
5. Comfort with mathematical formulas.	Very comfortable	32	20.0
	Comfortable	43	26.9
	Uncomfortable	45	28.1
	Very Uncomfortable	40	25.0
6. Amount of guidance needed	None	34	21.3
	Minimal	43	26.9
	Moderate	41	25.6
	Extensive	42	26.3
7. Helpfulness of visual aids	Extremely helpful	35	21.8
	Somewhat helpful	42	26.3
	Slightly helpful	44	27.5
	Not helpful	39	24.4
8. Preferred way to learn new physics concepts.	Hands-on experiments	44	27.5
	Watching demonstrations	34	21.3
	Group discussion	40	25.0
	Independent study	42	26.3

Table 4.1. continued

9. Need for more time to understand pendulum concepts.	Yes, a lot more time	38	23.8
	Yes, a bit more time	47	29.4
	No, current time is enough	42	26.3
	No, less time would be fine	43	20.6
10. Area best understood in the pendulum Experiment.	Theory	42	26.3
	Setup	46	28.3
	Data recording	34	21.3
	Data analysis	38	23.8
11. Confidence in conducting the experiment.	Very confident	33	20.6
	Somewhat confident	40	25.0
	Not very confident	47	29.4
	Not confident at all	40	25.0
12. Frequency of needing help with practical tasks.	Always	39	24.4
	Often	47	29.4
	Sometimes	40	25.0
	Never	34	21.3
13. Challenge in interpreting experimental results.	Very challenging	41	25.6
	Somewhat challenging	49	30.6
	Not very challenging	38	23.8
	Not challenging at all	32	20.0
14. Most enjoyable aspect of physics Experiments.	Hands-on work	45	28.1
	Learning theory	36	22.5
	Group work	42	26.3
	None of the above	37	23.1
15. Frequency of feeling lost/confused during practical work.	Very often	41	25.6
	Often	45	28.1
	Rarely	37	23.1
	Never	37	23.1

(Data Source: Field Data, 2025)

Table 4.1 indicates that, according to the comprehension of the relation between the length of the pendulum and its period, only 21.3% of the students indicated they comprehended this to a full extent. However, when summed up, the number of students who answered

"Somewhat," "Slightly," or "Not at all" amounted to 78.7% of the students, which implies that the majority of the students still did not have a full understanding of this basic law. The highest percentage (28.8%) showed that recording time was most difficult to perform, followed by graphing results (24.4%), determining the period (23.8%), and measuring length (23.1%). Similarly, in understanding simple harmonic motion, 21.1% showed that they understood it "Very well", whereas a total of 78.9% of the students selected "Fairly well", "Poorly", or "Not at all". This is a reflection that the majority of students require more guided support in understanding the theory underlying the experiment.

In terms of helpfulness of written instructions, about 22.5% of the students rated them in the "Extremely helpful" category, with the majority (77.5%) in the combined "Somewhat helpful", "Slightly helpful", or "Not helpful" categories. The suggestion is that written instructions alone may not be sufficient to cater to students' different learning needs in hands-on activities. Comfort level with using the mathematical formulas that are involved in pendulum motion, nearly half (46.9%) of the students were comfortable, selecting either "Very comfortable" (20.0%) or "Comfortable" (26.9%). On the other hand, slightly over half (53.1%) were uncomfortable, selecting either "Uncomfortable" or "Very uncomfortable". This indicates that the application of mathematical principles remains a limiting factor for the majority of the students.

Evidence also reveals that over half of the students needed additional support when carrying out practical experiments. While 21.3% indicated no need for any support, over half (51.9%) needed a lot or quite a lot of support. This is an indication that teachers should provide different levels of support when conducting laboratory exercises. Visual aids were also seen to be helpful by a section of the students, with 21.8.% having reported being

"Extremely helpful.". Nevertheless, 78.2% responded "Somewhat helpful", "Slightly helpful", or "Not helpful", showing that visuals by themselves may not be sufficient without other measures. When asked about what they enjoyed most in physics experiments, the majority of the students (28.1%) reported hands-on work, with 26.3% reporting group work. Fewer selected learning theory (22.5%), and 23.1% indicated none of the above. These results suggest that experiential, hands-on experience and collaboration are in general more engaging for students than theory. Slightly over half of the students (53.2%) reported needing more time. Comparatively, about a quarter (26.3%) found the allocated time sufficient, and 20.6% felt that even less time would be suitable. When questioned on which section of the simple pendulum experiment, they felt most at ease, the majority (28.3%) of the students chose setting up or theory (26.3%), while fewer students preferred data recording (21.3%) or data analysis (23.8%). This can be taken to mean that students feel more at ease with setup and concepts compared to accurate recording and analysis of data.

In terms of students' confidence to conduct the experiment independently, 20.6% of them reported being "Very confident". Students who were "Somewhat confident", "Not very confident", or "Not confident at all" totaled 79.4%, reflecting an overall self-lack of confidence to conduct the practical exercise independently. Over-reliance on support during practical lessons by students was also common. While 21.3% responded never needing help, more than three-fourths required some help: 24.4% "Always", 29.4% "Often", and 25% "Sometimes". In interpreting experimental results, around 25.6% of the students found this activity "Very difficult". Combined, 30.6% found it "Rather difficult" and 23.8% "Not very difficult", which means interpreting data is an area where most of the

students struggle with. More than half of them reported often being confused. Specifically, 25.6% of them said "Very often" and 28.1% "Often", while few of them responded that they sometimes or never felt confused.

The results indicate that the majority of students demonstrated limited understanding of both the theoretical concepts and practical skills involved in the simple pendulum experiment. Most students struggled with applying mathematical formulas, recording and analyzing data, and interpreting results, reflecting significant knowledge gaps and lack of confidence in conducting experiments independently. While hands-on and collaborative activities were more engaging than theory alone, written instructions and visual aids were insufficient to fully support students' learning needs. Overall, the findings suggest that differentiated guidance, additional practice, and more interactive support are essential to improve students' comprehension, confidence, and practical competencies in physics experiments.

Research Question 2*: What specific differentiated instructional strategies contribute significantly to improving senior high school physics practical performance in the simple pendulum experiment?*

To achieve Research Objective 2, the response of the students to statements that were used to measure their attitude toward some of the DI approaches and how they influenced experiential learning success in physics, namely in the case of the simple pendulum experiment. The responses were categorised into four scales of an agreement: Strongly Disagree, Agree, and Strongly Agree.

Table 4.2: 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, hands-on experiments, or lectures 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)

Table 4.2. continued

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 examinations, 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 enhances to me.	0 (0.0)	1 (1.3)	21 (26.3)	58 (72.5)

(Data Source: Field Data, 2025)

The responses of Table 4.2 reveal a highly positive trend towards DI. For instance, 66.3% of the students strongly agreed that the application of a mix of diverse modes of content presentation (e.g., visuals, practical work, and lectures) enhanced physics concept perception, while 5% disagreed. Another 52.5% strongly agreed that the variation of complexity based on students' perception was effective, which reveals high support for teaching flexibility. As regards learning in various modes, 58.8% of them strongly agreed that learning independently, with others, or through the assistance of peers improved their own learning. The students also appreciated trying out hands-on experience as more than 82% agreed or strongly agreed that it helped them comprehend things better. The research also indicates the significance of learning instruction based specifically on learning styles.

A notable 67.5% strongly agreed that modifications in teaching style by their instructor had a positive impact on their comprehension. Additionally, 66.3% strongly agreed that they would prefer to express their comprehension in more than one mode (oral, written, practical, or visual) as signifying preference for flexible testing strategies. On the testing side, 72.5% of students strongly agreed that flexibility in testing styles was important, and 63.7% felt comfortable demonstrating knowledge through doing, again highlighting student-centered testing styles.

The responses indicate a strong positive perception of Differentiated Instruction (DI) among students. The majority highly appreciated the use of diverse teaching methods, flexible pacing, and multiple modes of learning and assessment. Hands-on activities, peer-assisted learning, and adjustments in teaching style were reported to significantly enhance comprehension and engagement. Overall, the findings suggest that DI strategies, including varied content presentation and flexible testing, are effective in promoting understanding, accommodating different learning preferences, and supporting student-centered learning in physics.

To determine the degree to which the DI strategies could predict students' performance on the simple pendulum experiment, a multiple regression analysis (summery ANOVA shown in Table 4.3) was conducted. Differentiated instruction dimensions such as flexible assessment, multimodal content delivery, scaffolding, and learning style accommodation served as the predictors.

Table 4.3: ANOVA Summary for the Effect of DI Strategies on Physics Practical Performance

Source	Sum of Squares	df	Mean Square	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 = DI strategies (e.g., flexible assessment, hands-on experimentation, multimodal learning, scaffolding).

The whole model was significant, $F(15, 64) = 15.690$, $p < .001$, showing that the collection of DI techniques as a whole explained a significant amount of post-test performance variation. The regression sum of squares (SS = 605.760) explained about 79% of the total variance in students' performance, and the remaining 21% was explained by other variables that had not been measured. This shows that the DI techniques largely influenced the performance of students in the practical exercise.

To investigate further whether these attitudes were highly related to actual students' performance, a multiple linear regression with post-test scores of the simple pendulum experiment as the dependent variable and the 15 DI strategy items as predictors was conducted in Table 4.4.

Table 4.4: Results of Differentiated Instructional Strategies Predicting Students' Practical Performance

Predictor	B	Std. Error	Beta	T	Sig.
(Constant)	-10.525	4.301	—	-2.447	.017
1. Using different materials (textbooks, notes, visual aids)	0.381	0.299	0.088	1.277	.206
2. Content delivery methods (textbooks, visuals, experiments, lectures)	0.139	0.415	0.026	0.334	.739
3. Learning content broken into smaller steps	0.543	0.293	0.136	1.852	.069
4. Teachers adjust lesson complexity	0.778	0.331	0.175	2.348	.022
5. Additional resources (notes, simulations, guides)	0.366	0.304	0.083	1.204	.233
6. Preference for working individually/groups	0.361	0.371	0.060	0.974	.334
7. Active engagement in discussions	0.191	0.280	0.045	0.684	.497
8. Hands-on experimentation	1.912	0.416	0.449	4.592	.000
9. Teacher adapts to learning style	0.952	0.394	0.192	2.418	.018
10. Preferred learning style (visual, auditory, etc.)	0.223	0.283	0.051	0.789	.433
11. Preference for demonstrations (written, oral, etc.)	0.599	0.415	0.091	1.443	.154
12. Comfort with hands-on experiments	0.954	0.414	0.157	2.302	.025
13. Practical examinations/projects for assessment	-0.420	0.283	-0.096	-1.486	.142
14. Assignment options (practical vs. written)	0.771	0.310	0.177	2.486	.016
15. Flexibility in assessment methods	-0.061	0.393	-0.009	-0.156	.876

a. Dependent Variable: *Exp-Score*

b. Predictors: (Constant), Differentiated instructional strategies (Q1–Q15)

c**.** B (Unstandardised Coefficient), Beta (Standardised Coefficient)

As evident from Table 4.4, the model also provided some of the key findings. The global regression model was significant, and this proved that the DI perceptions explained a significant level of variance in the post-test scores of the students. Five predictors

(strategies) out of the 15 strategies were identified as statistically significant at $p < .05$, and these showed that the following components of DI had an understandable, measurable, and positive influence on practical performance outcomes.

Of particular importance, experiential learning was found to be the most powerful predictor of increased performance, with the largest standardised beta coefficient ($\beta = 0.449$, $p < .001$). Similarly, the perception that instruction was adjusted to accommodate learners' learning styles also emerged as a strong predictor of performance ($\beta = 0.192$, $p = .018$), and this attests to the importance of personalisation in teaching. The second significant predictor was the extent to which the instructor differentiated the complexity of lessons based on students' comprehension ($\beta = 0.175$, $p = .022$). Assurance in demonstrating comprehension with experiments was also a significant predictor of performance outcomes ($\beta = 0.157$, $p = .025$), implying that assurance boils down to actual accomplishment. Participants who had been told that they were presented with task options (e.g., writing or practice tasks) performed better in the experiment ($\beta = 0.177$, $p = .016$).

In order to observe the relative contribution of each predictor, Figure 4.1 displays the standardised contributions of the strategies addressed in the model. It is clear from the figure that strategies such as adjusted complexity of lessons, flexibility of the evaluation, hands-on experimentation, and presentation of the content through various modes had the greatest impact on students' outcomes. However, such predictors as group or individual working preference and step-by-step learning played a smaller but also a determining role.

Beta Coefficients of Differentiated instructional strategies nonstudents' Practical Performance

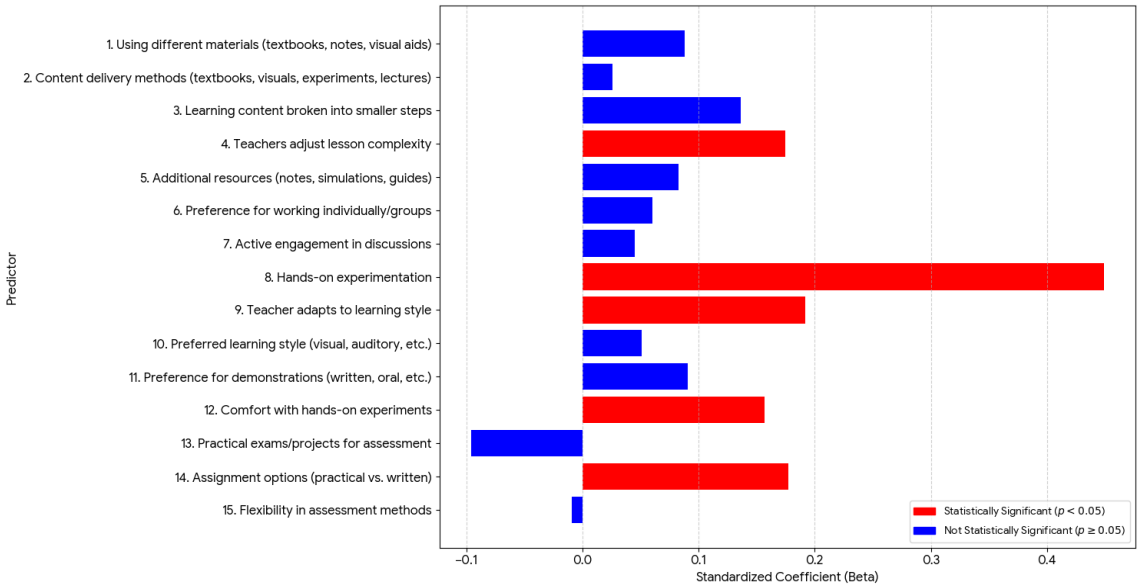

Figure 4.1: *Standardised Beta Coefficients of DI Strategies Predicting Students' Practical Performance*

On the other hand, some other variables such as content delivery mediums, other tools, collaborative methods, and tests did not predict performance directly with controls for other variables. Although these variables may still continue to have substantial effects on influencing engagement and motivation, they could be influenced by or overlap with stronger predictors mentioned above.

Research Question 3: *What are the attitudes of students towards DI in the physics laboratory setting?*

Descriptive statistical analysis was used in order to investigate students' attitude towards the various differentiated instructional strategies used in the physics lab. Responses of 80 students were collected on 15 statements, rated on a 4-point Likert scale with ratings of 1 (Strongly Disagree) to 4 (Strongly Agree).

Table 4.5: Results for Responses of Students' Attitudes Toward DI in the Physics Laboratory Setting

Item		N	Mean	Std. Deviation
1.	Different methods like videos, demonstrations, and group work help me understand physics.	80	3.36	.698
2.	I like it when lessons include both theory and hands-on experiments.	80	3.47	.675
3.	I prefer when physics experiments are explained step by step.	80	3.30	.701
4.	I understand physics concepts better when my teacher uses diagrams, videos, or models.	80	3.41	.610
5.	I like working in groups during laboratory experiments.	80	3.29	.732
6.	I understand concepts better when explained in multiple ways.	80	3.36	.621
7.	Experiment tasks can be changed to match different students' skill levels.	80	3.35	.658
8.	Extra help, clear instructions, or simpler materials make difficult experiments easier to do.	80	3.36	.680
9.	Understanding is checked during experiments, with extra explanations if needed.	80	3.49	.595
10.	Practicing experiments several times helps me learn better.	80	3.40	.739
11.	Step-by-step guides, simple notes, or visual aids make experiments easier to understand.	80	3.35	.677
12.	I prefer when my teacher gives different tasks to different students based on our strengths.	80	3.41	.669
13.	Using different ways to learn (videos, models, practice, peer support) makes physics more interesting.	80	3.34	.711
14.	Having options for tasks or different ways to show what I've learned helps me do better.	80	3.46	.615
15.	Using different strategies that match how students learn helps everyone understand physics better	80	3.46	.615

(Data Source: Field Data, 2025)

From Table 4.5, the overall scores across the items ranged from 3.29 to 3.49, all of which were above the cut-off value of a positive attitude of 2.50, indicating that, on average, the

students agreed or strongly agreed to all the statements. This suggests a general positive attitude towards DI in the physics laboratory. Highest mean rating (M = 3.49, SD = 0.595) for the item was "Understanding is checked in experiments, with additional explanations if necessary." It shows students value very much continuous support and immediate clarification during lab activities, a central aspect of responsive teaching. In close second were lesson planning and flexibility in testing items. For instance, students showed strong agreement with statements such as “I like it when lessons include both theory and hands-on experiments” (M = 3.47, SD = 0.675), “Having options for tasks or different ways to show what I’ve learned helps me do better” (M = 3.46, SD = 0.615), and “Using different strategies that match how students learn helps everyone understand physics better” (M = 3.46, SD = 0.615). These findings reflect a clear appreciation for teaching practices that incorporate diversity, personal interest, and student choice.

Students also appreciated the diversity of approaches used in instruction. Comments such as "Different strategies like videos, demonstrations, and collaborative work allow me to learn physics" (M = 3.36, SD = 0.698) and "I understand physics concepts better if my instructor uses diagrams, videos, or models" (M = 3.41, SD = 0.610) also support the notion that students learn more effectively from multi-modal content presentation. Instructional scaffolding also received a lot of support, as seen in responses to statements such as "I prefer it when physics experiments are described step by step" (M = 3.30, SD = 0.701) and "Step-by-step explanations, simple notes, or sketches make experiments easier to understand" (M = 3.35, SD = 0.677). Despite overall positive attitudes towards all the items, the item "I like working in groups during laboratory experiments" had the lowest mean (M = 3.29, SD = 0.732) - albeit above the 2.50 cut-off point - showing that although

collaborative learning is encouraged, individual student preference for group work is more divergent than for other approaches. The slightly larger standard deviation also indicates more divergent views on this particular aspect of the learning process.

The overall results indicate that students have a generally positive attitude towards Differentiated Instruction (DI) in the physics laboratory. They highly value responsive teaching that provides continuous support, immediate clarification, and step-by-step guidance during experiments. Students also appreciate diverse instructional strategies, including multi-modal content presentation, flexible lesson planning, and opportunities to demonstrate learning in different ways. While collaborative group work received slightly lower agreement compared to other aspects, it still reflected a positive attitude overall. These findings suggest that DI, through personalized, scaffolded, and varied instructional approaches, effectively supports student engagement, understanding, and learning preferences in physics laboratory settings.

Hypothesis, Ho: *There is no statistically significant difference in the practical performance of senior high school physics students who received DI and those who received traditional instruction in the simple pendulum experiment.*

Normality tests were carried out for both control and experimental group pre-test and post test scores to determine whether to apply parametric or non-parametric statistical analysis. The result is shown below in table 4.6.

Table 4.6: Tests of Normality for Pre-Test Scores and Post-Test Score by Group (Experimental group = 1 and Control group = 2)

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

a. Lilliefors Significance Correction

Values in Table 4.6 show that, Kolmogorov-Smirnov and Shapiro-Wilk tests were equally employed to check normality of the pre-test and post-test scores of the two groups. For the pre-test scores, Shapiro-Wilk test revealed that Group 1 did not significantly differ from normality (W = .975, p = .119), which implies that their pre-test scores were almost normally distributed. However, Group 2 pre-test scores were far from normal (W = .955, p = .007). Experimental group and control group pre-test scores were contrasted with each other using the Mann–Whitney U test (See Result presented in Table 4.7). Post-test scores for both groups significantly differed from normal: Group 1 (W = .950, p = .003) and Group 2 (W = .935, p = .001).

Table 4.7: 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

From Table 4.7, the results revealed that the two groups were not significantly different from one another (U = 3193.50, Z = –0.023, p = 0.982, two-tailed). This is evidence that the experimental and control groups were equal in pre-test performance prior to intervention. That there is no significant difference is a guarantee that any resulting change in post-test scores can be safely credited to treatment effect than to variation in baseline performance.

For comparison of experimental and control group post-test scores after intervention to further investigate the effect of DI on students' performance, descriptive statistics presented in Table 4.8 indicate two groups' summary of mean performance and variance, while Table 4.9 provides Mann–Whitney U test. These tests were conducted in an effort to determine if the differences in mean scores between students learning through DI and students learning through typical methods were statistically significant.

Table 4.8: **Descriptive Statistics of Post-Test Scores for Experimental and Control Groups**

	Group	N	Mean	Std. Deviation	Std. Error Mean
Post-Test Score	1	80	15.38	3.156	.353
	2	80	12.99	1.436	.161

The results indicate that Group 1 (n = 80) had a higher mean post-test score (M = 15.38, SD = 3.16) compared to Group 2 (M = 12.99, SD = 1.44, n = 80). The lower standard deviation for Group 2 indicates that their scores are more centralised around the mean, while scores for Group 1 were minimally spread out. The standard errors (.353 for Group 1 and .161 for Group 2) show that the means of the samples are very good approximations of the population means.

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 control group taught through traditional instruction.

Table 4.9: 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

The analysis 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 DI,

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 (see Appendix X for Mann–Whitney U Test and Calculation of Effect Size r for Post-Test Scores)

4.2 Discussion

Learning needs of senior high school physics students in conducting a simple pendulum experiment

Table 4.1 results illustrate disparate learning needs and conceptual gaps in the senior high school students' performance in conducting the simple pendulum experiment. That only 21.3% of the students fully understood the relationship between pendulum length and period is an indication of a conceptual gap. This conforms to current literature emphasising the difficulty of relating theoretical concepts to experimental validation in physics (Holmes & Wieman, 2018; Dounas-Frazer & Lewandowski, 2018). From constructivist thought, such difficulty can be explained by minimal experience of working actively with phenomena and therefore abstract concepts are not incorporated into robust mental models (Bruner, 1966; Piaget, 1970).

The overwhelming prevalence of challenges in measurement of time, graphing the data, and calculating the duration is an indicator that procedural and analytical skills require specific intervention According to the West African Examinations Council (2023), many students continue to struggle with measurement accuracy and graphing skills during Physics practical activities, limiting their ability to validate theoretical predictions. Vygotsky's (1978) Zone of Proximal Development (ZPD) predicts that such skill deficit

can be assisted constructively with scaffolding, like teacher modelling, guided practice, and peer-assisted learning.

Low mathematical equation use confidence (exhibited by more than half of the students) demonstrates the interconnectedness of physics competence and mathematical proficiency. Ghanaian and other empirical work confirms that without fluency in equation handling, students will tend to analyse experimental data poorly (Antwi et al., 2021; Doucette et al., 2024). DI, with tiered sets of problems, scaffolded supports, and adaptive pacing, is particularly well suited to address these diverse levels of readiness (Tomlinson, 2017; Abamba et al., 2024).

The finding that over half of the students required moderate or high levels of teacher support reinforces the need for more facilitation during lab sessions. Smale-Jacobse et al. (2019) point out that effective practical learning is fostered where direct teaching is supplemented by co-working among peers to facilitate procedural autonomy. Moreover, the minimal usefulness students placed upon static materials such as printed instructions or images shows that multimodal and interactive support may be more beneficial (Abamba, et al., (2024)

Application of cooperative and experiential learning aligns with research that these approaches maximise participation, motivation, and retention of acquired knowledge (Ojo, 2022; Bada & Akinbobola 2020). The request by so many students for additional time, however, highlights a requirement for the differentiation of pacing to accommodate different rates of processing and learning styles (Santoso et al., 2025).

Finally, low self-efficacy in carrying out the experiment on their own (reported by 79.4% of the participants; corresponds with the repeated loopholes highlighted in the WAEC Chief Examiners' Reports (WAEC, 2021; 2022; 2023; 2024), wherein procedural abilities, data analysis, and graph interpretation remain major problems. The widespread confusion among students during the interpretation of results correlates with earlier research by Kidega and Zheng (2024) who identified inefficiency in data analysis and inference in Ghanaian physics classrooms.

Together, these outcomes indicate that the learners require:

i. **Enhanced conceptual understanding** of pendulum principles through active learning with support.
ii. **Enriched procedural understanding** of measurement taking, recording, and graph plotting, supported by guided practice.
iii. **Mathematical aid embedded within experimental contexts** to reinforce the use of equations.
iv. **Tailorable instructional pace and specific guidance** to foster confidence and autonomy.

These needs strongly justify the use of DI in physics practical instruction. As Antwi et al. (2021) and Abamba et al. (2024) illustrate, offering instruction in content, process, and product in response to students' readiness levels (providing systematic scaffolding) closes skill gaps, enhances confidence, and improves overall performance in physics experiments like the simple pendulum.

Specific DI strategies that contribute significantly to improving SHS physics practical performance in the simple pendulum experiment

The findings in Tables 4.2 and 4.3 indicate that students' performance in physics practical activities was significantly explained by specific DI strategies. The explanatory value of the model (≈79%) indicates that instruction adjusted to learners' readiness, interests, and learning preferences significantly affects achievement results. This confirms Tomlinson's (2017) assertion that differentiation aims to respect learner diversity and optimises access to higher-order ideas. Regression analysis identified five most important predictors (practical hands-on experience, teacher accommodation to learning styles, adjusting the level of difficulty in lessons, facilitation by students in demonstrating understanding via experimentation, and providing alternatives for assignments) as the most powerful factors enhancing performance.

Practical experimentation was the strongest predictor ($\beta = 0.449$, $p < .001$). This outcome agrees with other research highlighting the central position of active engagement in physics learning. Antwi et al. (2021) and Bada and Akinbobola (2020) demonstrated that direct manipulation of equipment, observation of physical phenomenon, and immediate feedback reinforce conceptual knowledge and foster process skill. Similarly, the Ghanaian senior high school physics syllabus gives significant emphasis to laboratory experiments to promote accuracy, precision, and problem-solving. Active experimentation on pendulum apparatus in this study enabled students to relate theoretical equations (e.g., $T=2\pi\sqrt{(l/g)}$) to concrete outcomes, hence reducing misconceptions (Kidega & Zheng, 2024).

Adaptation of instruction by the instructor to meet the cognitive styles of learners ($\beta = 0.192$, $p = .018$) further helped with performance. This is endorsed by constructivist theory, where one learns that learners construct knowledge more effectively when instruction is adapted to their prior knowledge and cognitive styles (Piaget, 1970; Bruner, 1966).

Responsive teaching strategies (such as visual demonstration, auditory description, and kinesthetic manipulation) are in consonance with the work of Abamba et al. (2024), who proved that instruction aligned to several learning styles enhances conceptual retention in physics.

Adjusted lesson difficulty based on students' preparedness ($\beta = 0.175$, $p = .022$) also supports Vygotsky's (1978) Zone of Proximal Development, which postulates scaffolding content slightly above the independent ability of the learner. In this present study, decomposing initial instructions and gradually progressing towards more complex procedures likely allowed less confident learners to build competency before progression to advanced problem-solving.

The ease with which students demonstrated understanding through experimental hands-on ($\beta = 0.157$, $p = .025$) is proof that procedure confidence carries over to measurable accomplishment. Smale-Jacobse et al. (2019) reported that laboratory proficiency not only enhances performance but also develops grit to battle experimental hardship. Providing repeated opportunities for equipment manipulation and error-and-correction learning, as utilized in this investigation's DI approach, likely boosted students' self-efficacy; a noteworthy motivational construct in science performance (Abamba et al., 2024).

Offering assignment options ($\beta = 0.177$, $p = .016$) also had a positive effect, according to the product differentiation principle of DI (Tomlinson, 2001). Allowing students to choose, for instance, between a written laboratory report or oral/practical presentation, provided students with scope for exercising autonomy in their strengths and making personal choices. Adaptive modes of assessment have been proven to encourage student

engagement and autonomous learning in physics practical work (Doucette, D'Urso, & Singh, 2024).

Conversely, surprisingly, interventions such as diversifying modes of content delivery, assistance with resources, and cooperative learning (although positively scored by students) did not by themselves forecast attainment in the regression model. This may indicate that their impacts on achievement are indirect, acting through more powerful predictors such as active experimentation and responsive scaffolding. Although previous studies (e.g., Buabeng et al., 2014) confirm the participation benefits of these strategies, their tangible effect on performance outcomes appears to be mediated by more experiential and student-focused approaches.

Attitudes of students towards DI in the physics laboratory setting

Analysis of students' responses (Table 4.5) revealed consistently positive mean ratings ranging from 3.29 to 3.49, all exceeding the 2.50 cut-off point for a positive attitude. This demonstrates that students generally hold favourable views toward DI in physics laboratory settings. The most highly rated activity, *"Understanding is checked during experiments, with extra explanations if needed"* (M = 3.49, SD = 0.595), reflects students' appreciation for continuous formative assessment and just-in-time scaffolding. This finding aligns with Vygotsky's (1978) Zone of Proximal Development, which emphasises that learners achieve more under guided interaction. In laboratory contexts, such support allows conceptual gaps to be addressed early, enabling learners to consolidate understanding before advancing.

Similarly, high levels of agreement were reported for integrating theory and practice (M = 3.47, SD = 0.675) and for providing multiple pathways to demonstrate learning (M = 3.46, SD = 0.615). These results support constructivist perspectives (Piaget, 1970; Bruner, 1966), which advocate for active engagement and diverse modes of learning to strengthen conceptual mastery. They also corroborate findings by Abamba et al. (2024), who showed that combining DI with active learning cycles boosts student self-efficacy and engagement in physics classes.

Students further expressed positive attitudes toward the use of varied instructional media such as videos, diagrams, and models (M = 3.36–3.41). This is consistent with Abamba et al. (2024), who demonstrated that multimodal content delivery supports diverse learning styles and facilitates recall. Likewise, favourable impressions of step-by-step descriptions and illustrations (M = 3.30–3.35) echo Kidega and Zheng (2024), who found that clear procedural instructions reduce cognitive load during practical tasks, especially for learners with limited prior knowledge.

Interestingly, the lowest mean score, though still positive, was associated with group work during experiments (M = 3.29, SD = 0.732). This suggests that while collaborative learning is widely recognised as beneficial in science education (Smale-Jacobse et al., 2019), its effectiveness depends on group dynamics, task clarity, and learner preferences. The variability of responses resonates with caution that collaboration without clearly defined roles or objectives may not benefit all learners equally.

Overall, the findings indicate that students value differentiated teaching strategies that provide flexibility, variety, and immediate support in laboratory exercises. These results

are consistent with prior research showing that DI enhances engagement (Antwi et al., 2021), strengthens conceptual understanding, and accommodates learner diversity by adjusting content, process, and product to readiness levels (Tomlinson, 2001; 2017). The findings also point to the need for refining group learning strategies so that collaborative tasks remain structured, purposeful, and aligned with student comfort levels.

Difference in practical performance of students who received DI and those who received traditional instruction in simple pendulum experiment

This current study investigated the effect of DI on practical performance of senior high school physics students on the simple pendulum experiment. The result revealed that there was a major advantage to students taught with DI compared to students taught using conventional instruction.

A baseline equivalence between the experimental and control groups through the Mann–Whitney U test provided no statistically significant difference between them prior to the intervention ($U = 3193.50$, $Z = –0.023$, $p = .982$). This provides assurance that both groups began with equivalent practical competence, securing the internal validity of the research further by ensuring post-test differences were ascertainable through the instructional method and not through differences in advance.

A Mann–Whitney U test revealed a statistically significant difference between post-test scores by groups, as the experimental group ($M = 15.38$, $SD = 3.16$) was greater than the control group ($M = 12.99$, $SD = 1.44$), $U = 1691.00$, $Z = –5.19$, $p < .001$. Effect size was $r = .41$, which was a medium-to-large practical effect according to Cohen's (1988) criteria. This confirms that DI not only improved student performance but did so with substantial practical significance. This finding is consistent with previous research that indicates DI

supports higher conceptual knowledge, procedural knowledge, and scientific practical confidence than traditional teaching (Salar & Turgut, 2021; Dounas-Frazer & Lewandowski, 2018).

The findings also coincide with experiment outcomes in Ghanaian contexts. Antwi et al. (2021) similarly recorded significant gains in students' scientific process skills and physics attitude after DI-based interventions, whereas Abamba et al. (2024) also identified that the combination of DI with organised learning cycles enhanced performance, especially among lower- and mid-achievers. The significant effect size of this study also supports Tomlinson's (2017) argument that learner readiness, interest, and learning profile-based instruction can profoundly boost accomplishment in diverse classrooms. The null hypothesis was rejected. Differentiated instruction was also far better than normal teaching in enhancing students' experimental skills on the simple pendulum experiment, as corroborated by its potential to be an efficient pedagogical approach in senior high school physics education.

Figure 4.2: *Comparison of pre-test and post-test mean scores for experimental and control groups in the simple pendulum experiment.*

These findings are corroborated by the graphical trends in Figure 4.2 and 4.3. Figure 4.2 shows that pre-test means scores for the two groups were almost the same, upholding the observation that baseline performance levels were the same. The post-test bars, on the other hand, present a very clear differentiation of performance, with the experimental group possessing much higher scores. The improvement is depicted by the box plot of Figure 4.3 below, where the post-test of the experimental group has a wider spread and median, indicating that more students achieved higher levels of performance. Minimal progress is depicted by the control group's decreased post-test spread, as indicated by the lower reported mean and less variability.

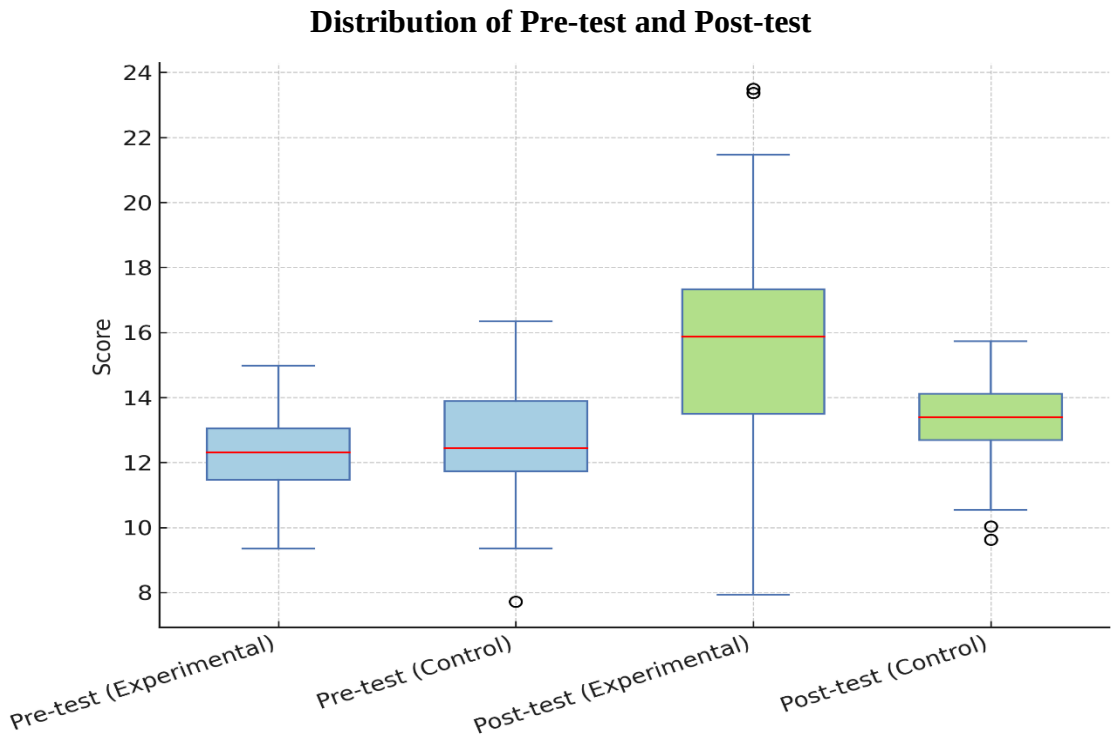

Figure 4.3: *Distribution of pre-test and post-test scores for experimental and control groups in the simple pendulum experiment.*

The study sought to examine the effect of DI on the practical performance of senior high school students in the simple pendulum experiment. Results showed a clear performance advantage for students taught with DI compared to those who were exposed to conventional methods.

Baseline comparisons using the Mann–Whitney U test showed that no statistically significant difference existed between the experimental and control groups at the pre-test level ($U = 3193.50$, $Z = –0.023$, $p = .982$). This shows that the two groups began the intervention with equal levels of practical competence, and it contributes to the internal validity of the study by making post-test differences explainable through the instructional intervention and not through starting differences.

Post-test comparison was statistically significantly different for the two groups. A Mann–Whitney U test revealed that the experimental group ($M = 15.38$, $SD = 3.16$) outperformed the control group ($M = 12.99$, $SD = 1.44$), $U = 1691.00$, $Z = –5.19$, $p < .001$. The effect size was $r = .41$, which was a medium-to-large practical effect. This finding demonstrates that the intervention not only generated statistical significance but also practical significance in enhancing the practical performance of the students.

These findings are consistent with earlier research evidence that DI enables greater conceptual comprehension, practical skills, and student interest compared to traditional instruction. Antwi et al. (2021) found identical gains in Ghana, where DI-based physics interventions considerably enhanced students' scientific process skills and attitudes toward experimental work. Likewise, Abamba et al. (2024) found that the integration of DI with active learning cycles promoted performance and confidence, particularly among low- and mid-achieving students. International comparative research also reveals that DI supports more profound learning through content, process, and assessment individualization based on students' readiness and interest levels (Salar & Turgut, 2021). These align with Tomlinson's (2017) argument that DI optimises access to rigorous ideas through adapting learning opportunities to learner differentiation.

Based on these results, the null hypothesis was rejected. Differentiated instruction was found to be considerably more effective than traditional teaching in enhancing students' practical performance in the simple pendulum experiment. The results confirm that DI should be prioritised as a teaching strategy in senior high school physics classrooms to bridge conceptual gaps, strengthen practical capability, and foster enhanced performance in general.

4.3 Summary

This chapter investigated the influence of DI on the experiential performance of senior high school students studying physics in the simple pendulum experiment. The discussion started by raising questions about the diverse learning needs of the learners, where there were vast gaps in conception, procedural difficulties, and confidence levels. Most of the students were having difficulty reading time, graphing results, applying mathematical equations, and reading experimental data and required moderate to high levels of assistance. These findings guided the design of scaffolded, student-driven strategies that adjust content, pacing, and support to levels of readiness.

The research then measured student attitudes towards specific DI strategies. Regression analysis showed five predictors of improved practical performance as experimentation in practical work, adaptation of teacher learning style, adjustment of lesson difficulty, explanation of understanding in detail through practical work, and providing choices for the work. Among them, experimentation in practical work was the best predictor and emphasises the central role of practical work in physics learning. Attitudes in favor of DI were robust among students who scored high on mean measures of methods that were mixed practice-theory, had more than one way of measuring, exhibited multimodal materials, and gave instant feedback in the laboratory.

Comparative statistical analysis indicated that experimental and control groups were equal on the pre-test but post-test scores were statistically and practically different in favour of the DI group (Cohen's d = 0.97). Visual graph representation also evidenced the findings with higher means, higher score variation, and better medians for the experimental group. These results align with constructivist theory and Vygotsky’s Zone of Proximal

Development, suggesting that DI's adaptive, scaffolded approach effectively bridges gaps between conceptual understanding and practical execution. Overall, the chapter provides robust evidence that DI can enhance physics practical performance by meeting students' diverse needs through flexible, responsive, and hands-on learning experiences.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

This chapter presents the culmination of the study by synthesising key findings, drawing meaningful conclusions, and proposing actionable recommendations.

5.2 Key Findings

The study yielded some key findings that widely enrich the understanding of DI and how it can be effective for physics practical training in Ghana:

Pre-test analysis confirmed that there was no statistically significant practical performance difference between the experimental and control groups prior to the intervention ($U = 3193.50$, $p = .982$). This ensured initial group equivalence, in that any later differences in performance could safely be attributed to instructional strategy rather than existing differences. This concurs with Tomlinson's (2001) recommendation that equal starting points need to be achieved in order to allow a clear evaluation of pedagogical effect.

Post-test results indicated a statistically significant improvement in the practical performance of the experimental group ($M = 15.38$, $SD = 3.156$) compared to that of the control group ($M = 12.99$, $SD = 1.436$), $t(110.39) = 6.159$, $p < .001$. The magnitude of this improvement was considerable, as reflected by a large effect size (Cohen's $d = 0.97$). This robust finding supports the work of Antwi et al. (2021), which indicated that adaptive, focal instructional methods could greatly enhance scientific process ability. It also agrees with the outcomes of which determined that multi-strategy, learner-centred instruction surpassed standard, uniform instruction in achieving conceptual mastery.

Student reactions, collected using systematic questionnaires, indicated highly favourable reception to the implemented DI approaches. Respondents strongly endorsed the value of experiential experimentation, dynamically changing lesson difficulty, multimodal presentation of content, sequential procedural directions, flexible formats of assessment, and real-time feedback provision. This outcome supports the fundamental tenets of Vygotsky's (1978) Zone of Proximal Development, which highlights the significance of scaffolding instruction to learners' levels of readiness. It also aligns with Abamba, et al. (2024), who demonstrated that heterogeneous learning materials enhance comprehension and retention of abstract physics concepts.

Above all, the study demonstrated that DI is not only theoretically sound but also practically feasible and highly effective in resource-poor Ghanaian classrooms. The strategic alignment of scaffolded assignments, tiered activities based on student readiness, and increased learner autonomy yielded meaningful, measurable gains in procedural fidelity, skills in data interpretation, and overall student engagement. This observation confirms the conclusion of Smale-Jacobse et al. (2019) that DI is an adaptive and versatile approach that can bring favourable outcomes to a range of educational settings.

5.3 Conclusion

This study categorically establishes that DI significantly contributes to the hands-on skills of senior high school students in physics, specifically in conducting the simple pendulum experiment. Empirical studies suggest that DI not only results in a statistically significant improvement in students' practical performance and conceptual understanding but also enhances their motivation compared to the conventional, one-size-fits-all instruction. The

size of the effect (r = .41) indicates a medium-to-large size of improvement, signifying that the difference not only is statistically significant but also educationally significant in improving students' learning outcomes.

These results strongly confirm the theoretical underpinnings of DI as explicated by Tomlinson (2001), supporting that acting in advance to differentiate content, process, and product according to students' differing readiness levels and learning styles has a direct impact on achievement. Empirical studies confirm Antwi et al. (2021) results within the Ghanaian context, showing that instructionally focused strategies effectively sustain scientific process skills and counter common misconceptions. Moreover, effectiveness in intervention also provides a practical illustration of Vygotsky's (1978) Zone of Proximal Development, showing the way scaffolding, learner-centered activity within the laboratory setting enables learners to achieve competence beyond independent ability.

The conformity of these results with international studies by Abamba et al. (2024) affirms the international value of adaptive learning processes and multimodal materials. The worldwide positive student receptiveness, in alignment with research by Kidega and Zheng, (2024), certifies that such adaptive procedures are not only effective but also highly stimulating for students, instilling confidence and scientific self-efficacy.

Lastly, this research validates that DI is a very effective, efficient, and essential pedagogical approach to improving the quality of physics teaching at senior high schools. Its effectiveness in a resource-scarce environment ensures its practicability and adaptability.

5.4 Recommendations

Based on the compelling evidence of this study, the following practicable recommendations are made to the key stakeholders to enhance physics practical education and bridge the theory-practice gap in senior high schools, particularly in resource-poor settings like Ghana.

1. Teacher training institutions and professional development organisations need to mainstream differentiated instruction (DI) into their core programmes in ways that reflect the particular conditions of Mampong Municipality and Sekyere Central District. Many physics teachers posted to these districts begin teaching with limited exposure to practical DI strategies, often relying on lecture-based methods because of large class sizes and variability in students' foundational knowledge. Training institutions should therefore move beyond theoretical presentations and provide experiential practice using realistic classroom scenarios drawn from schools in the two districts. This includes simulations of physics lessons in crowded classrooms, modelling how to diagnose diverse learning needs, and designing tiered tasks using inexpensive local materials. By giving teachers sustained opportunities to practise flexible grouping, modify content, and design varied assessments, the colleges would align with Tomlinson's (2001) emphasis that DI requires deliberate, structured preparation.
2. For the Ghana Education Service and the Ministry of Education, there is a need to invest in DI toolkits and basic physics laboratory equipment targeted specifically at the resourced-constrained schools typical of Mampong and Sekyere Central. Many schools in these districts lack the materials required for routine experiments,

forcing teachers to rely on abstract explanations that hinder conceptual understanding. To counter this, policymakers should supply low-cost, high-impact equipment such as metre rules, lenses, pendulums, resistors, springs, and stopwatches. Complementing this should be the development of DI toolkits containing multi-level worksheets, scaffolded instructions, and locally adaptable experiment guides. These resources would enable teachers to differentiate lessons even in low-resource environments, echoing evidence from Antwi et al. (2021) that supported practical work is essential for meaningful learning in physics.

3. School administrators and physics department heads in Mampong and Sekyere Central must encourage a shift toward adaptive, student-focused pedagogies within their institutions. Leadership support is crucial because many teachers in these districts face high workloads and limited planning time, which makes it difficult to implement DI consistently. Administrators can strengthen DI practice by allocating collaborative planning periods, fostering professional learning communities where teachers exchange differentiated lesson ideas, and recognising teachers who innovate with flexible instructional approaches. By promoting varied forms of assessment—such as oral explanations, practical demonstrations, and group investigations—schools can nurture multiple student strengths. This aligns with Smale-Jacobse et al. (2019), who argue that diversification of assessment enhances learning outcomes.
4. National curriculum and policy developers also play a critical role in supporting schools in Mampong and Sekyere Central. The science curriculum and accompanying syllabi need revisions that explicitly recommend DI as a guiding

pedagogical framework. Currently, teachers in the two districts receive curricular documents with uniform expectations, leaving them to interpret how to adapt lessons for mixed-ability classes. Integrating concrete examples of how to adjust content, process, and product for key physics topics would help teachers translate DI theory into daily practice. Clear guidance on flexible pacing, scaffolded tasks, and differentiated practical work would create the organisational backing necessary for sustained reform, consistent with the insights of Kidega and Zheng (2024).

5. Finally, physics teachers and practitioners in these two districts should prioritise proactive diagnosis of misconceptions and use targeted scaffolding to address learning gaps. Given that many students enter SHS in Mampong and Sekyere Central with uneven preparation in mathematics and basic science, early identification of misconceptions is essential. Teachers can administer brief diagnostic activities, practical skill checks, or conceptual pre-tests at the start of each unit to reveal areas of difficulty. Instruction can then be differentiated through scaffolded worksheets, guided practice, structured peer support, and tiered assignments that challenge advanced learners while supporting those who struggle. This targeted approach, advocated by Diack and Lawson (2017), builds procedural competence and enhances student confidence—two critical outcomes for physics learning in these districts.

With implementation of these stakeholder-specific recommendations, the Ghanaian education system can effectively translate the auspicious discoveries of this study into real practice to result in a more inclusive, interactive, and effective environment for physics education.

5.5 Future Research Direction

Although the present study provides strong evidence supporting the positive impact of DI on physics practical performance, further studies would be needed to replicate and extend these findings. Future studies might examine the long-term effect of DI across a series of physics topics and practical activities beyond the simple pendulum experiment. These studies would help determine whether these performance gains observed are sustained in the long term and are transferable to other areas of the physics course (Smale-Jacobse et al., 2019).

Since the research was conducted in only two senior high schools within the Ashanti Mampong Municipality and Sekyere Central District, replication across various geographical settings and school milieus in Ghana is preferred. This would enhance generalisability of the findings and account for variation in resources, teacher competence, and student groups, as encouraged to determine DI's efficacy in low-resource contexts (Akyeampong, 2017; Smale-Jacobse et al., 2019).

Subsequent research would look into the integration of DI with other student-centered approaches, such as inquiry-based learning (Abamba et al., 2024) and cooperative learning strategies (Smale-Jacobse et al., 2019), to determine whether pedagogical interventions in combination yield even higher improvements in student performance and motivation.

Finally, further research could investigate the role of teacher professional development in implementing DI successfully because teacher capacity is a determinant of DI success (Santangelo & Tomlinson, 2012; Tomlinson, 2017). Research in this area can provide evidence of the best training models, support structures, and provisions of resources

necessary for scaling DI where resources are limited. Finally, further studies could investigate the role of teacher professional development in implementing DI effectively, given that teacher capacity is a key determinant of successful differentiation (Tomlinson, 2001; Santangelo & Tomlinson, 2012). Research in this area could provide insights into the most effective training models, support systems, and resource provisions necessary for scaling DI in resource-limited educational contexts.

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APPENDICES

Appendix A – Research Instruments

A1: Students' Physics Practical Performance Test a (Pre-test)

Answer all questions

1.The time period of a simple pendulum is defined as:
   a) Time for half a swing
   b) Time for one complete oscillation
   c) Time to reach maximum speed
   d) Time until the pendulum stops

2.The correct formula for a pendulum's period is:
   a) $T=2\pi g/LT=2\pi g/L$
   b) $T=2\pi L/gT=2\pi L/g$
   c) $T=2\pi m/gT=2\pi m/g$
   d) $T=2\pi m/LT=2\pi m/L$

3.Which variable does not affect the period of a pendulum?
   a) Gravitational acceleration
   b) Length of string
   c) Mass of the bob
   d) Small-angle amplitude (<15°)

4.To measure a pendulum's period accurately, you must use a:
   a) Ruler
   b) Spring balance
   c) Stopwatch
   d) Thermometer

5.The length of a pendulum is measured from:
   a) Bob's top to floor
   b) Pivot to bob's center
   c) String's end to pivot
   d) Tabletop to bob's bottom

6.If the pendulum's length is doubled, its period:
   a) Becomes unpredictable
   b) Decreases by half
   c) Remains unchanged
   d) Increases by $\sqrt{2}$ times

7.In a T2T2 vs. LL graph, the expected trend is:
   a) Exponential curve
   b) Horizontal line
   c) Parabolic curve

d) Straight line through origin

8.A student records 20 oscillations in 18.4s. The period TT is:

a) 0.92s
b) 0.96s
c) 1.04s
d) 1.08s

9.In a pendulum experiment, which action would most improve measurement accuracy?

a) Increasing the amplitude to 30°
b) Measuring length from the tabletop
c) Timing more oscillations
d) Using a heavier bob

10. If a pendulum is taken to the Moon, how does its period change?

a) Becomes unpredictable
b) Decreases (Moon's gravity < Earth's)
c) Increases (since $T \propto 1/gT \propto 1/g$)
d) Remains the same

Set up a simple pendulum of length L=20.0 cm. Displace the bob so that the pendulum swing in a vertical plane about its equilibrium position. Determine the timer for 20 oscillations.

11. Repeat the procedure for L=40.0. Record your results in the table below.

Length (m)	Time for 20 oscillations (t, s)	Mean (t, s)
20.0		
40.0		

12. Answer the following questions based on your experiment:

a. State two precautions taken during the experiment:

i. ……
ii. ……

b. State two factors that affect the period of a pendulum:

i. ……
ii. ……

A2: Students' Physics Practical Performance Test b (Post-test)

Instructions: Answer all questions

1. The time period of a simple pendulum is best defined as the time for:
   a) for the string to become taut.
   b) one complete back-and-forth swing.
   c) the bob to move from left to right.
   d) to reach half the maximum height.
2. If the length of a pendulum is quadrupled, its period will:
   a) Double (since T $\propto \sqrt{L}$).
   b) Halve.
   c) Increase by four times.
   d) Remain unchanged.
3. The force responsible for bringing the pendulum bob back to equilibrium is:
   a) Air resistance acting opposite to motion.
   b) Centrifugal force.
   c) The horizontal component of gravity.
   d) The vertical component of tension.
4. To measure the angle of displacement accurately, you would use a:
   a) Meter stick.
   b) Protractor.
   c) Spring balance.
   d) Stopwatch.

5 The correct way to measure pendulum length is from:
   a) The bob's top to the pivot.
   b) The pivot point to the bob's center.
   c) The string's top to its midpoint.
   d) The tabletop to the bob's bottom.

6. In an experiment testing T vs. L, the dependent variable is:
   a) Amplitude of swing.
   b) Length of the string.
   c) Mass of the bob.
   d) Time period.
7. A graph of T^2 vs. L for a pendulum should yield:
   a) A horizontal line (no relationship).
   b) A parabolic curve.
   c) A straight line through the origin (T^2 vs. L).
   d) An exponential curve.

8. Which does not influence the pendulum's period?
   a) Bob color.
   b) Local gravitational acceleration.
   c) Small-angle amplitude (<15°).
   d) String length.
9. To minimise error in period measurements, you should:
   a) Use a lighter bob.
   b) Time at least 20 oscillations. *(Correct)*
   c) Displace the bob at 45°.
   d) Ignore air resistance.
10. A student times 15 oscillations in 12.6 seconds. The period (T) is:
   a) 0.63 s
   b) 0.75 s
   c) 0.84 s
   d) 1.26 s

11. A pendulum of length 60.0 cm is set up. Complete the table below by:
   - Measuring the time for 15 oscillations (twice).
   - Calculating the mean period T.

Trial	Time for 15 oscillations (s)	Period T = t/15 (s)
1		
2		
Mean		

12. a. State two errors to avoid in the experiment:
   b. i) Ensure the pendulum swings in a _____ (plane/arc).
   ii) Use a _____ (small/large) angle to maintain SHM.
   iii) Reduce _____ (air resistance/friction) by using a smooth, dense bob and avoiding _____ (wind/curved) surfaces near the setup.

A3: Structured Student Questionnaire on Differentiated Instruction

Instruction: *Please tick in the box where applicable*

PART 1: Background Information

A. Age: [ ] Under 15 [ ] 15-16 [ ] 17-18 [ ] Over 18

B. Gender: [ ] Male [ ] Female

PART 2

Learning Needs and Challenges in Simple Pendulum Experiments

1. Do you understand the relationship between pendulum length and oscillation period?
   [ ] Yes, completely [ ] Somewhat [ ] Slightly [ ] Not at all
2. Which areas of the pendulum experiment do you find challenging?
   [ ] Measuring length [ ] Recording time [ ] Calculating period [ ] Graphing results
3. How well do you understand the concept of simple harmonic motion?
   [ ] Very well [ ] Fairly well [ ] Poorly [ ] Not at all
4. How helpful do you find written instructions when setting up experiments?
   [ ] Extremely helpful [ ] Somewhat helpful [ ] Slightly helpful [ ] Not helpful
5. How comfortable are you working with the mathematical formulas involved in pendulum motion? [ ] Very comfortable [ ] Comfortable [ ] Uncomfortable [ ] Very uncomfortable
6. How much guidance do you typically need during physics experiments?
   [ ] None [ ] Minimal [ ] Moderate [ ] Extensive
7. How helpful are visual aids such as diagrams for understanding the experiment?
   [ ] Extremely helpful [ ] Somewhat helpful [ ] Slightly helpful [ ] Not helpful
8. What is your preferred way to learn new concepts in physics?
   [ ] Hands-on experiments [ ] Watching demonstrations [ ] Group discussion
   [ ] Independent study
9. Do you feel you need more time to understand the concepts in the pendulum experiment?
   [ ] Yes, a lot more time [ ] Yes, a bit more time [ ] No, current time is enough
   [ ] No, less time would be fine
10. Which area of the simple pendulum experiment do you understand best?

[ ] Theory [ ] Setup [ ] Data recording [ ] Data analysis

11. How confident are you in conducting this experiment on your own?

[ ] Very confident [ ] Somewhat confident [ ] Not very confident [ ] Not confident at all

12. How often do you need help to complete practical tasks in physics?

[ ] Always [ ] Often [ ] Sometimes [ ] Never

13. Do you find interpreting the results from your experiments challenging? [ ] Very challenging [ ] Somewhat challenging [ ] Not very challenging[ ] Not challenging at all

14. Which aspect of physics experiments do you find most enjoyable?

[ ] Hands-on work [ ] Learning theory [ ] Group work [ ] None of the above

15. How often do you feel lost or confused during physics practicals?

[ ] Very often [ ] Often [ ] Rarely [ ] Never

PART 3:

Identify specific differentiated instructional strategies that positively impact the practical performance of senior high school physics students in simple pendulum experiments.

Instruction: *Please tick the box that best represents your experience.*

1. Using different materials like textbooks, notes, and visual aids helps me understand physics theory better.

   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

2. Content delivery methods like textbooks, visuals, hands-on experiments, or lectures help me understand physics concepts better.

   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

3. I find it easier to learn when content is broken into smaller steps.

   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

4. It is effective when teachers adjust lesson complexity based on my understanding.

   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

5. Additional resources like simplified notes, extra materials, simulations, or step-by-step guides help me understand physics practicals better.

   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

6. I prefer working individually, in groups, or with demonstrations/peer assistance during physics practical lessons.

   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

7. I actively engage in discussions during physics practical lessons.
   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
8. Hands-on experimentation helps me understand physics concepts better.
   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
9. My teacher adapts teaching approaches to match my learning style.
   [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
10. I find my preferred learning style (visual, auditory, kinesthetic, reading/writing) useful for physics practicals.
    [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
11. I prefer demonstrating my understanding through written, oral, practical, or visual presentations. [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
12. I feel comfortable demonstrating my understanding through hands-on experiments.
    [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
13. Practical exams, projects, or other assessments help me show my knowledge best.
    [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
14. Having assignment options (practical vs. written) improves my performance.
    [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree
15. Flexibility in assessment methods is important to me.
    [ ] Strongly Disagree [ ] Disagree [ ] Agree [ ] Strongly Agree

PART 4

Students' Attitude Questionnaire (SAQ)

Instruction: *For each statement, please indicate your level of agreement on a scale from 1 to 4, where 1 means "Strongly Disagree", 2 "Disagree", 3 "Agree" 4 "Strongly Agree"*

S/N	ITEM	1	2	3	4
1	Different methods like videos, demonstrations, and group work help me understand physics.				
2	I like it when lessons include both theory and hands-on experiments.				
3	I prefer when physics experiments are explained step by step.				
4	I understand physics concepts better when my teacher uses diagrams, videos, or models.				
5	I like working in groups during lab experiments.				
6	I understand concepts better when explained in multiple ways.				
7	Experiment tasks can be changed to match different students' skill levels.				
8	Extra help, clear instructions, or simpler materials make difficult experiments easier to do.				
9	Understanding is checked during experiments, with extra explanations if needed.				
10	Practicing experiments several times helps me learn better.				
11	Step-by-step guides, simple notes, or visual aids make experiments easier to understand.				
12	I prefer when my teacher gives different tasks to different students based on our strengths.				
13	Using different ways to learn (videos, models, practice, peer support) makes physics more interesting.				
14	Having options for tasks or different ways to show what I've learned helps me do better.				
15	Using different strategies that match how students learn helps everyone understand physics better				

Thanks for your honest participating

Appendix B – Statistical Analysis Outputs

B1: Internal Consistency for Part 1, 2 and 3 of the Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.769	.067	27

B2: Internal Consistency for Pre-Test multiple choice section and Inter – Rater Reliability for Essay Section

Reliability Statistics

Reliability Statistics	**Value**	**Value N of Items/Valid Cases**
Cronbach's Alpha	.739	10
Measure of Agreement (Kappa)	.847	20

B3: Normality Test Outputs (Kolmogorov–Smirnov & Shapiro–Wilk)

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	Df	Sig.	Statistic	df	Sig.
Post-Test Score	1	.116	80	.010	.950	80	.003
	2	.191	80	.000	.935	80	.001

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Post_Test_Score	1	.116	80	.010	.950	80	.003
	2	.191	80	.000	.935	80	.001

a. Lilliefors Significance Correction

B4: Mann–Whitney U Test Output (Pre-test Comparison)

Test Statistics[a]

	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

B5: Mann–Whitney U Test Output (Post-test Comparison)

Test Statistics[a]

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

a. Grouping Variable: Group

B6: Calculation of Effect Size r

Step 1. Interpret the SPSS table

U = 1691.00

Z = –5.194

p < .000 (Asymp. Sig. 2-tailed) → **highly significant**

N = 160 (80 experimental + 80 control)

Step 2. Calculate the effect size r

Formula: $r = \frac{|Z|}{\sqrt{N}}$

$r = \frac{5.194}{\sqrt{160}}$

$\sqrt{160} = 12.649$

$r = \frac{5.194}{12.649}$

r = 0.41

Effect size r = .41 (medium-to-large effect)

B7: Descriptive Statistics Tables

Descriptive Statistics of Students' Perceptions of Differentiated Instructional Strategies in Physics Practical Lessons

	N	Minimum	Maximum	Mean	Std. Deviation
1. Different methods like videos, demonstrations, and group work help me understand physics.	80	2	4	3.36	.698
2. I like it when lessons include both theory and hands-on experiments.	80	2	4	3.47	.675
3. I prefer when physics experiments are explained step by step.	80	2	4	3.30	.701
4. I understand physics concepts better when my teacher uses diagrams, videos, or models.	80	2	4	3.41	.610
5. I like working in groups during lab experiments.	80	2	4	3.29	.732
6. I understand concepts better when explained in multiple ways.	80	2	4	3.36	.621
7. Experiment tasks can be changed to match different students' skill levels.	80	2	4	3.35	.658
8. Extra help, clear instructions, or simpler materials make difficult experiments easier to do.	80	2	4	3.36	.680
9. Understanding is checked during experiments, with extra explanations if needed.	80	2	4	3.49	.595
10. Practicing experiments several times helps me learn better.	80	1	4	3.40	.739

11. Step-by-step guides, simple notes, or visual aids make experiments easier to understand.	80	2	4	3.35	.677
12. I prefer when my teacher gives different tasks to different students based on our strengths.	80	2	4	3.41	.669
13. Using different ways to learn (videos, models, practice, peer support) makes physics more interesting.	80	2	4	3.34	.711
14. Having options for tasks or different ways to show what I've learned helps me do better.	80	2	4	3.46	.615
15. Using different strategies that match how students learn helps everyone understand physics better	80	2	4	3.46	.615
Valid N (listwise)	80				

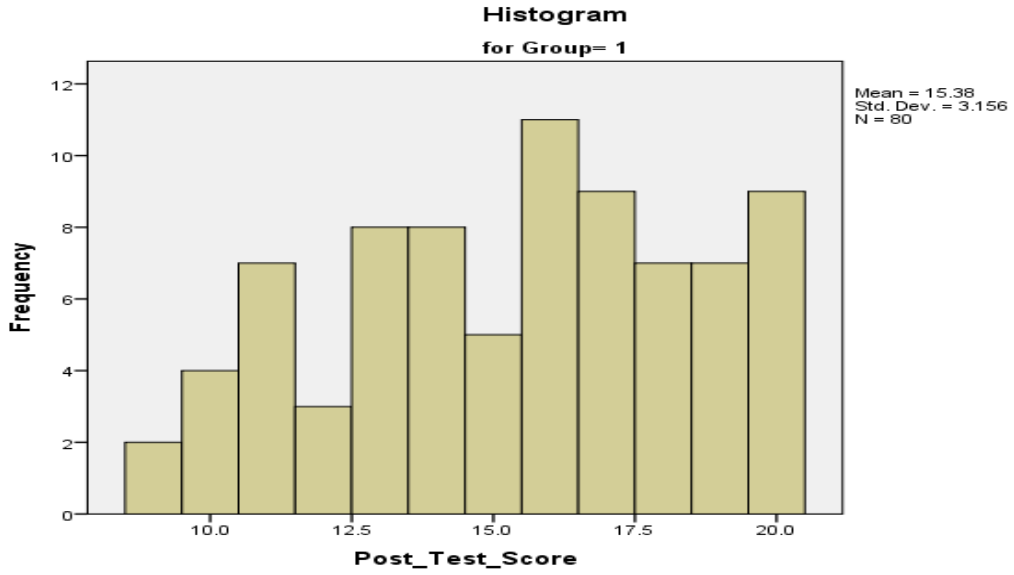
B8: Descriptive Statistics of Post-Test Scores for Experimental and Control Groups

	Group			Statistic	Std. Error
Post_Test_Score	1	Mean		15.38	.353
		95% Confidence Interval for Mean	Lower Bound	14.67	
			Upper Bound	16.08	
		5% Trimmed Mean		15.44	
		Median		16.00	
		Variance		9.959	
		Std. Deviation		3.156	
		Minimum		9	
		Maximum		20	

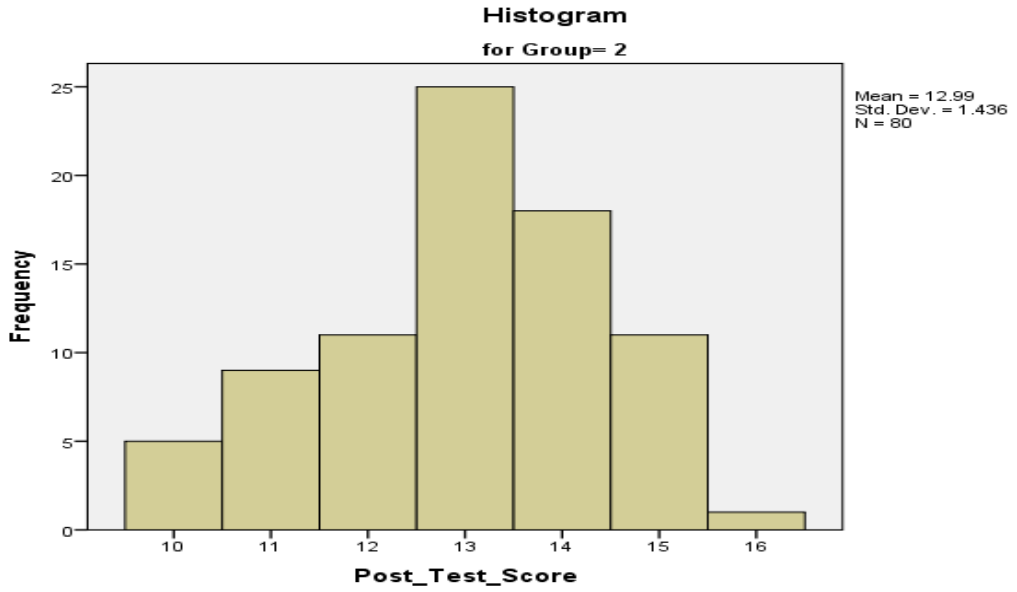
		Range		11	
		Interquartile Range		5	
		Skewness		-.238	.269
		Kurtosis		-.969	.532
	2	Mean		12.99	.161
		95% Confidence Interval for Mean	Lower Bound	12.67	
			Upper Bound	13.31	
		5% Trimmed Mean		13.03	
		Median		13.00	
		Variance		2.063	
		Std. Deviation		1.436	
		Minimum		10	
		Maximum		16	
		Range		6	
		Interquartile Range		2	
		Skewness		-.346	.269
		Kurtosis		-.451	.532

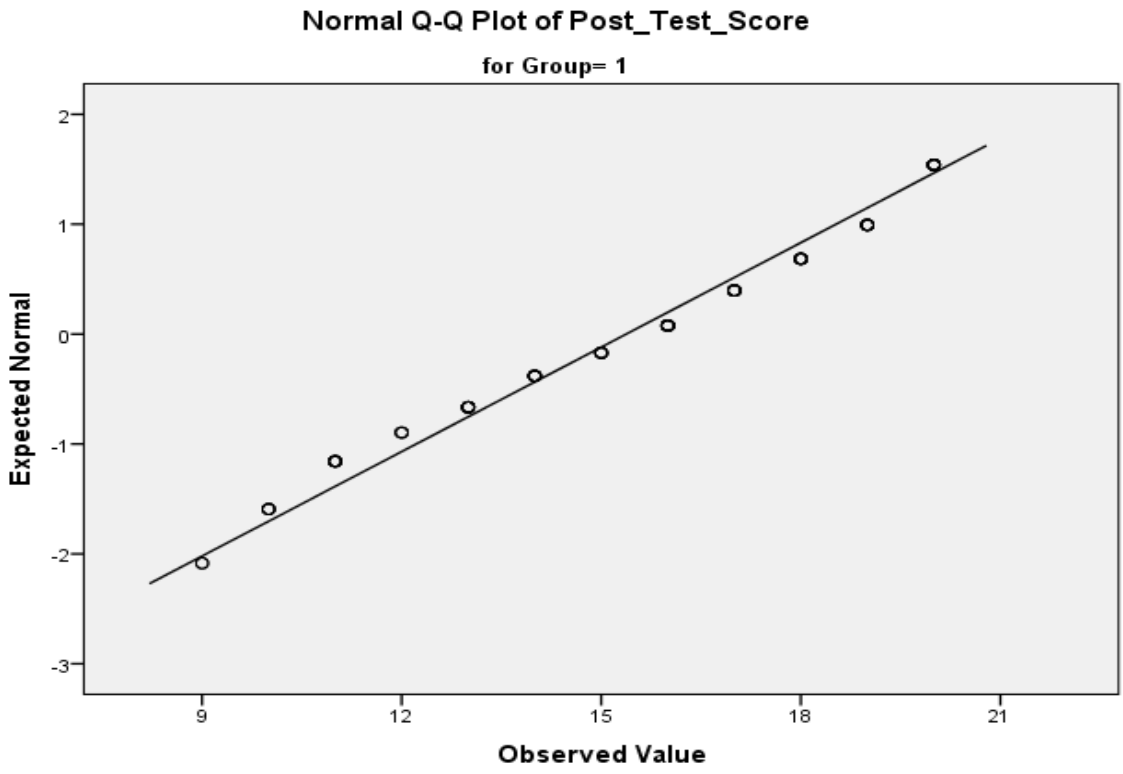
Appendix C – Figures and Visual Representations

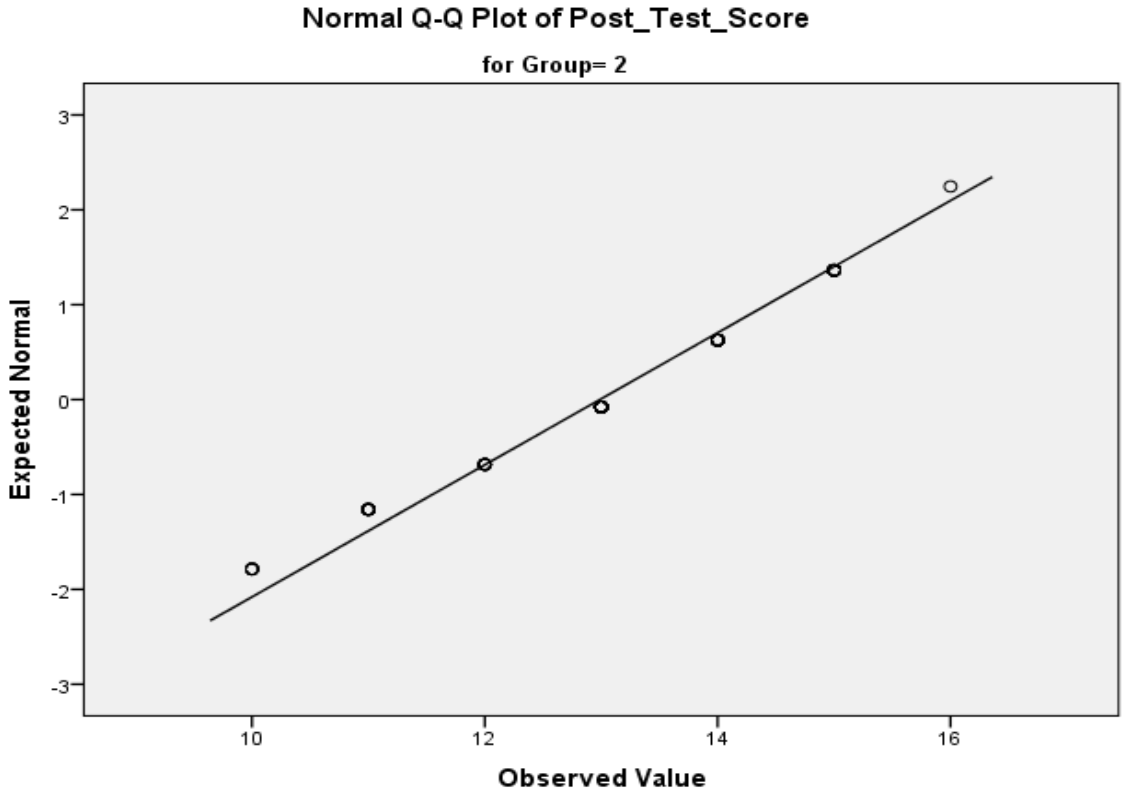
Distribution of Post-Test Scores for the Experimental Group Taught with Differentiated Instruction



Distribution of Post-Test Scores for the Control Group Taught with Traditional Instruction






Normal Q-Q Plot of Post_Test_Score
for Group= 2
Expected Normal
3
2
1
0
-1
-2
-3
10
12
14
16
Observed Value