UNIVERSITY OF EDUCATION, WINNEBA

LABORATORY EFFICIENCY OF PHYSICS STUDENTS IN MECHANICS AND OPTICS IN LASSIA TUOLU SENIOR HIGH SCHOOLS

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DECLARATION

Student's Declaration

I, FUSEINI THOMAH declare that this dissertation, with the exception of quotations and references contained in published works, which have all been identified and duly acknowledged, is entirely my own original work and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:……………………………

DATE:………………………………………

Supervisors' Declaration

I, Dr. Ernest Ngman-Wara, hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

SIGNATURE:……………………………

DATE:………………………………………

DEDICATION

This dissertation is dedicated to my wife, Samiel Mariyam

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I am most grateful to my supervisor Dr. Ernest Ngman-Wara, for his expert guidance, support and encouragement. Without him, the completion of this dissertation would not have been possible. I am sincerely thankful to my wife (Samiel Mariyam) for being there for me and supporting me in all my endeavours.

I cannot end without thanking Sumalia Seidu Thomah, Imoru Seidu Thomah, Inusah Seidu Thomah and Nurideen Seidu Thomah. My lovely children, Najati and Nihad also deserve special mention. I also wish to thank my coursemates, who, in diverse ways assisted me during this programme.

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ABSTRACT

This study investigated laboratory efficiency of SHS 3 Physics students in mechanics and optics at Lassia Tuolu Senior High School in the Wa West District. It used census sampling technique to select 54 SHS 3 students. A descriptive survey design was employed. Data were collected through practical performance test and questionnaire. The data were analysed using frequencies, percentages, means, standard deviation and t-test statistics. The findings revealed that students demonstrated an average level of proficiency across all assessed laboratory skills, with particularly strong performance in performing tasks. Additionally, no significant gender differences were observed in laboratory efficiency. Moreover, the study revealed that laboratory efficiency among senior high school Physics students in mechanics and optics was generally well supported by adequate resources, positive learning environments, effective teacher guidance, and favorable student attitudes, although time constraints, irregular practical sessions, and varying levels of student confidence moderately limited its full effectiveness. Based on these findings, it is recommended that Lassia Tuolu Senior High School science teachers provide students with increased opportunities to engage in hands-on, authentic laboratory activities to further enhance their practical skills and scientific reasoning. Lassia Tuolu Senior High School should also provide regular and structured laboratory activities that encourage all students, regardless of gender, to actively participate in experimental work

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter provides the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, delimitations, limitations and organisation of the study.

1.1 Background to the Study

Physics is fundamental to understanding our world and drives both economic growth and societal well-being (Unamma & Onah, 2025). The expertise of physicists is vital across many sectors, and in our fast-paced, technological era, a population educated in physics is crucial for making informed decisions (Abubakar, 2012). Therefore, physics literacy is a key component of general knowledge for all citizens. Furthermore, advancing our understanding of physics is an exciting intellectual pursuit that benefits from diverse perspectives on national development.

The study of physics is crucial to understanding the world around us, the world inside us, and the world beyond us (Edgren, 2019). In many respects, physics is the most basic and fundamental natural science. It involves universal laws and the study of the behaviour and relationships among a wide range of important physical phenomena (Cutnell & Johnson, 2007). Physics challenges our imaginations with concepts like relativity and string theory, and it leads to great discoveries, like computers and lasers, that change our lives. It encompasses the study of the universe from the largest galaxies to the smallest subatomic particles. Moreover, it's the basis of many other sciences, including chemistry, oceanography, seismology, and astronomy.

Physics also leads to an understanding of many practical applications and ideas in other areas of science. Laboratory work within physics education is a strategy to improve students' conceptualisations about physical phenomena. Theoretically, experimental laboratory work should improve learning. It uses multiple representations, offers physical manipulatives, and embodies cognition (Gustavsson, 2021).

Physics, as a science, is crucial in explaining the events that occur within the universe. Physical rules and principles can be observed in virtually everything around us, from the motion of planets to the operation of household appliances (Boo et al., 2017). For example, understanding Newton's laws of motion allows students to predict the trajectory of a thrown ball or analyze the forces acting on a car navigating a curve. The field of physics has experienced several revolutions in the 21st Century, from classical mechanics to quantum physics and relativity, each transforming our understanding of natural phenomena. According to Commeford et al. (2021), laboratory practices in engineering and physics classes are essential for college students, as they help develop critical experimental skills, analytical reasoning, and mental tools necessary for knowledge processing in experimental physics. Engaging in hands-on laboratory activities, such as measuring the acceleration due to gravity using a pendulum or investigating electrical circuits, enables students to connect theoretical concepts to real-world applications, thereby enhancing comprehension and fostering problem-solving abilities. This also aids students' management of basic concepts, helps them to know the worth of observation and to differentiate between interference created in theory and what is discovered in practice (Bhathal, 2011). Learners improve their abilities to grasp higher-level concepts and apply them personally.

Physics principles form the foundation for many fields of engineering and applied sciences. It is accepted that science laboratory work gives scholars an opportunity to generate experimental and analytical ideas to correlate links between theories and observation. (Bhathal, 2011). This allows students to develop their ability to manipulate instruments, to perform experiments, and to gather knowledge. These techniques also allow for cooperative learning and to incorporate skills of analyses into their behaviours.

Laboratory administrators at the school level assume that first hand expertise in observation and manipulation develops understanding and appreciation. Laboratory instruction is also often used to develop skills required for advanced scientific study and research. The target considerations are the acquisition of adequate science laboratory resources and their effective utilization for student's performance in physics (Frank & Tuinhof, 2009). The tutorial experience involving the learner's activated problems solving skills maintains knowledge acquisition longer than abstract experiences (Yousuf, 2005). As for the place of learning, young physicists should have access to necessary data, materials and resources. They need to interact with tangible and intangible resources so as to ensure learner-centered activities are an integral part of learning science (Frank & Tuinhof, 2009). Laboratories with inadequate materials have had an adverse effect on performance in science (Lal et al., 2017). In short, laboratory facility has a direct effect on students' learning processes. This may help students to build positive attitudes towards physics studies (Olufunke, 2012).

Multiple representation is a pedagogical practice where a concept or a process is represented in different forms, as can be done during laboratory work in physics education. By only using one representation to a concept, it is easily misunderstood as that representation may highlight a particular feature (Tripathi, 2008). However, implementing multiple representations for a concept promotes a deeper understanding and may also build a bridge for the student between abstract and concrete representations (Hsu, 2016).

Physical manipulatives are physical objects that are helpful when teaching a concept. They can help alter students' physical imagery of a concept, and thus again offer a bridge between what is abstract and what is concrete (Schwartz et al., 1962). Experimental laboratory work is also a way of embodying cognition, as it requires a high level of student activity. There has, during the second half of the 20th century until today, been a re-thinking of the nature of cognition, towards promoting cognition as an embodied activity (Anderson, 2003). The traditional view on cognition describes cognitive processes as computational, where learning is mental. This has shifted towards learning as integrated with the sensorimotor system. The physical actions that a student performs influence the student's mental experience and understanding (Sullivan, 2018), and since experimental laboratory work is a way of including the students' sensorimotor system this should prove beneficial for the student's learning, according to the theories of embodied cognition.

In their efforts to develop and validate instruments to assess laboratory skills of students in high school physics courses, Ossei-Anto (1996) and Johnson (2001) produced prototype instruments for assessing the level of skills possessed by physics students. The method of science laboratory procedure adopted by Ossei-Anto (1996) and Johnson (2001) consists of three categories: planning, performing and reasoning which can be likened to the pre-lab, lab and post-lab activities that take place in most of Ghana's senior high school science classes.

During the planning stage, students work on designing basic experimental procedures to a problem. In the performing stage, students carry out actual experiments, manipulate objects, make observations, record data, and take decisions about a practical strategy. During the reasoning/analysis stage, students process data, explain relationships, form generalizations, discuss data accuracy, and provide sources of error and limitations to an experiment. The model for this research follows that of Ossei-Anto (1996) and Johnson (2001).

1.2 Statement of the Problem

Laboratory work plays a critical role in the effective teaching and learning of physics, as it allows students to link theoretical concepts with practical experiences. However, at Lassia Tuolu Senior High School in the Wa West District, many senior high school students continue to face challenges in demonstrating proficiency during physics laboratory sessions, particularly in mechanics and optics. This lack of laboratory competence hinders their understanding of core physics concepts and limits their ability to apply theoretical knowledge to practical problems, ultimately affecting their academic performance and interest in pursuing careers in science, technology, engineering, and mathematics (STEM) fields (Bhathal, 2011; Bateman et al., 2014).

Previous studies indicate that low engagement in laboratory activities often stems from students' insufficient practical skills. Jalil et al. (2020) reported that many students exhibit limited participation in laboratory experiments due to a lack of requisite skills, which results in disengagement and minimal enthusiasm.

Similarly, Lal et al. (2017) observed that students often struggle to understand the design and implementation of experiments, leading to difficulties in interpreting results accurately. These challenges are further compounded by inadequate laboratory equipment and resources, as highlighted by Kumar (2010) and Bateman et al. (2014), which restrict students' opportunities to conduct experiments effectively. At Lassia Tuolu Senior High School, this problem is reflected in the general low performance of physics students, as observed in practical exercises. Students frequently struggle to trace light paths through triangular glass prisms, accurately measure incident, emergent, and deviation angles, or indicate the correct direction of light rays. Such deficiencies mirror findings in the 2023 Chief Examiners' Report for Ghana, which revealed widespread inaccuracies in practical physics tasks.

Furthermore, many educators contend that students demonstrate inadequate skills in planning, performing, and reasoning during traditional laboratory activities (Johnson, 2001; Olufunke, 2012). Given these challenges, it becomes crucial to investigate the laboratory efficiency of physics students in mechanics and optics at Lassia Tuolu Senior High School, to identify specific areas of deficiency and inform strategies for enhancing practical competency in physics education.

1.3 Purpose of the Study

The study examined laboratory efficiency of Physics students in mechanics and optics in Lassia Tuolu Senior High School in the Wa West District.

1.4 Research Objectives

The research objectives of the study were to:

1. Examine the extent to which Lassia Tuolu Senior High School physics students exhibit skills of Planning, Performing and Reasoning during practical work.
2. Examine the difference between male and female students' laboratory efficiency skills in mechanics and optics
3. Determine the factors that affect the laboratory efficiency of Lassia Tuolu Senior High School physics students in mechanics and optics.

1.5 Research Questions

To address the challenges faced by senior high school (SHS) physics students in developing laboratory skills, the issues were refined into specific research questions. These guided the study and were formulated as follows:

1. To what extent do Lassia Tuolu Senior High School physics students exhibit skills of Planning, Performing and Reasoning during practical work?

2. To what extent do male and female students differ in their laboratory efficiency skills in mechanics and optics?
3. What factors affect the laboratory efficiency of Lassia Tuolu Senior High School physics students in mechanics and optics?

1.6 Significance of the Study

The outcomes of this research will provide valuable insights for authorities in Lassia Tuolu Senior High School aiming to improve the quality of physics education at the school. Physics educators can benefit by discovering effective methods to boost students' laboratory efficiency at Lassia Tuolu Senior High School. Additionally, SHS students at Lassia Tuolu Senior High School may become more aware of the importance of developing strong laboratory skills, which could lead to better academic achievement in physics.

1.7 Delimitations of the study

This study was confined to SHS3 physics students within the Wa West District. The focus was specifically on the laboratory efficiency of students at Lassia Tuolu Senior High School. The investigation centered on the skills of planning, performing, and reasoning in selected mechanics topics (machines) and optics topics (refraction rhrough a glass prism) a glass prism. Other laboratory methodologies or scientific approaches were not considered.

1.8 Limitations of the Study

The study could not include all students in Lassia Tuolu Senior High School, but this was not possible due to inadequate resources, funds and constraints of time. Moreover, because some of the students were not regular in school, it may affect the results of the study. Biases and the inherent flaws associated with the use of data collection instruments as a tool for data collection will be some of the setbacks of this study. In some cases, the uncooperative attitude of some of the respondents threatened the data collection efforts of the researcher.

1.9 Organisation of the Study

The research is structured into five main chapters. The first chapter introduces the study, covering the background, problem statement, objectives, research questions, importance, scope, and overall organisation. The second chapter presents a review of related literature, divided into theoretical, conceptual, and empirical frameworks.

The third chapter outlines the research methodology, detailing the study design, target population, sampling methods, data collection tools, procedures for gathering and preparing data, analytical techniques, and ethical considerations. The fourth chapter presents and discusses the research findings. The final chapter summarises key outcomes, offers conclusions, and provides recommendations.

CHAPTER TWO

REVIEW OF LITERATURE

2.0 Overview

This chapter gives account of the relevant literature reviewed in support of the research. The literature reviewed has been systematically organised under the following sub headings: physics as a course of study, teaching and learning of physics, the concept of mechanics and optics, gender differences in science performance assessment and factors affecting the laboratory efficiency of senior high school physics students.

2.1 Theoretical Framework

This study was grounded in the Constructivist Learning Theory, which provides a comprehensive explanation for how students develop laboratory efficiency through active engagement in practical learning experiences. Constructivism views learning as an active, dynamic process in which learners construct their own understanding based on interaction with their environment, prior knowledge, and social experiences. This perspective is particularly relevant to science education, where learners are expected to move beyond memorization and develop practical competence through experimentation and inquiry. The theory is strongly associated with the works of Jean Piaget and Lev Vygotsky. Piaget (1972) emphasised that learning occurs through the processes of assimilation and accommodation, where individuals integrate new experiences into existing cognitive structures and modify those structures when necessary. In the context of physics laboratory work, students are exposed to real-life phenomena in mechanics and optics, such as motion, forces, and light behavior, which challenge their prior understanding and require them to reconstruct their knowledge through experimentation. This active engagement allows learners to develop deeper conceptual understanding and practical competence.

Vygotsky (1978) extended constructivist ideas by emphasizing the importance of social interaction in learning. He introduced the concept of the Zone of Proximal Development, which explains that learners can achieve higher levels of understanding when supported by more knowledgeable individuals such as teachers or peers. In physics laboratory settings, this support is evident through teacher guidance, collaborative group work, and structured inquiry activities. These interactions play a crucial role in enhancing students' laboratory efficiency, as they provide opportunities for clarification, feedback, and shared problem-solving. Constructivist theory further posits that meaningful learning occurs when students are actively involved in tasks that require exploration, manipulation, and reflection. In laboratory-based physics instruction, students engage in designing experiments, manipulating apparatus, making observations, and interpreting results. These activities align with the core laboratory skills of planning, performing, and reasoning, which form the basis for assessing laboratory efficiency in this study. Through repeated engagement in such tasks, students gradually develop the ability to think scientifically, solve problems, and apply theoretical knowledge in practical situations.

Empirical studies in science education support the application of constructivism in laboratory learning. Hofstein and Lunetta (2004) assert that laboratory activities are most effective when they involve inquiry-based approaches that actively engage students in the learning process. Similarly, Etkina and Planinšič (2015) highlight that hands-on and student-centered laboratory experiences significantly enhance students' scientific reasoning and experimental skills. These findings reinforce the idea that laboratory efficiency is not merely a function of exposure to experiments but depends on the quality of students' engagement and participation. Constructivism also provides insight into the influence of contextual factors on learning outcomes. According to

Jerome Bruner (1961), effective learning environments must provide appropriate resources and scaffolding to support knowledge construction. Inadequate laboratory equipment, insufficient instructional guidance, and limited opportunities for practice can therefore hinder students' ability to engage meaningfully in laboratory activities, thereby reducing their efficiency. Additionally, students' attitudes and motivation toward laboratory work influence their level of participation and engagement, which ultimately affects their learning outcomes.

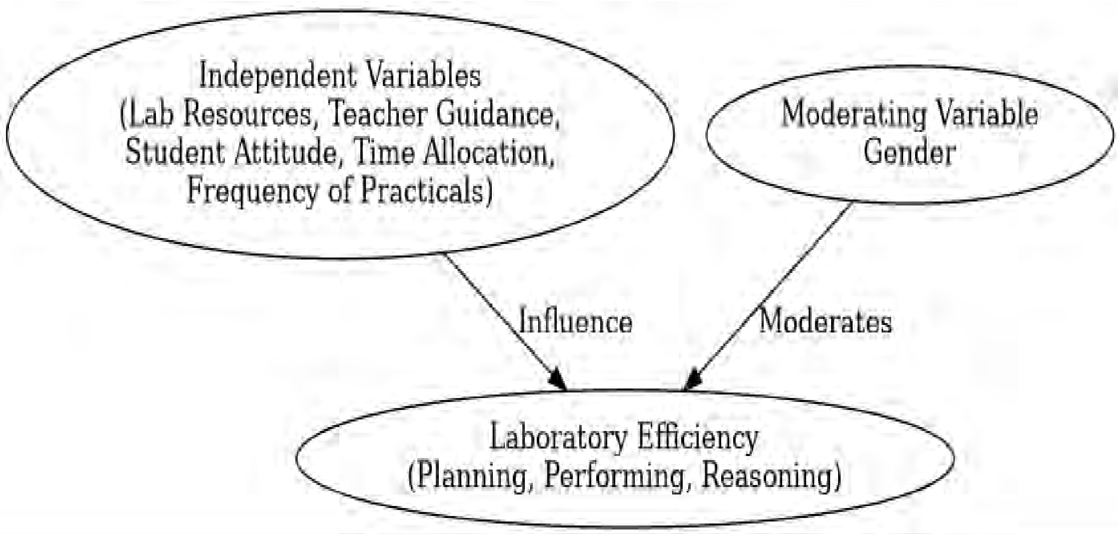
Furthermore, the theory aligns with the concept of embodied cognition, which suggests that learning is enhanced when cognitive processes are linked with physical activity. Anderson (2003) argues that physical interaction with learning materials plays a critical role in shaping understanding. In physics laboratories, students interact directly with apparatus, perform measurements, and observe physical phenomena, thereby integrating mental and physical processes. This integration enhances both conceptual understanding and practical skill development. In relation to this study, Constructivist Learning Theory provides a strong foundation for explaining how students develop laboratory efficiency in mechanics and optics. It suggests that laboratory efficiency is a result of active engagement in experimental activities, where students construct knowledge through experience, interaction, and reflection. The theory also explains how factors such as laboratory resources, teacher guidance, time allocation, and student attitudes influence students' ability to effectively plan, perform, and reason during laboratory work. Therefore, constructivism not only supports the focus of this study but also provides a framework for understanding the processes through which laboratory efficiency is developed.

2.2 Conceptual Framework

The conceptual framework of the study is presented in Figure 1.

Figure 1

Conceptual Framework



The conceptual framework for this study presents a clear relationship between the variables that influence laboratory efficiency among senior high school physics students. It explains how selected factors interact to determine students' ability to effectively carry out laboratory activities in mechanics and optics.

In this study, laboratory efficiency is considered the dependent variable and is operationalized through three core components: planning, performing, and reasoning skills. These skills represent the sequential stages of laboratory work, beginning with the design of an experiment, followed by its execution, and concluding with the analysis and interpretation of results.

The framework identifies several independent variables that influence laboratory efficiency. These include laboratory resources, teacher guidance, student attitude, time allocation, and frequency of practical activities. Laboratory resources refer to the availability and adequacy of equipment and materials necessary for conducting experiments. When resources are sufficient, students are more likely to engage actively in laboratory work and develop the required skills. Teacher guidance plays a crucial role in facilitating learning by providing instructions, demonstrations, and feedback, which help students understand procedures and correct mistakes. Student attitude reflects learners' interest, motivation, and perception of laboratory work, which significantly affect their level of engagement and persistence during practical activities. Time allocation determines whether students have adequate opportunity to complete experiments thoroughly and reflect on their outcomes, while the frequency of practical activities influences the extent to which students gain repeated exposure and practice in laboratory skills.

In addition to these variables, gender is considered a moderating variable in the study. It is expected to influence the relationship between the independent variables and laboratory efficiency. This is based on existing literature suggesting that male and female students may differ in their interaction with laboratory tasks, although such differences are often context-dependent.

The conceptual framework therefore suggests that laboratory efficiency is not determined by a single factor but is the result of the interaction of multiple variables within the learning environment. Improvements in laboratory resources, instructional support, and student engagement are likely to enhance students' ability to plan, perform, and reason effectively during laboratory activities. Conversely, limitations in these areas may hinder the development of laboratory efficiency.

2.3 Physics as a Course of Study

Physics, as the aspect of science that deals with the structure of matter and the interactions between the fundamental constituents of the observable universe, is concerned in the broadest sense with all aspects of nature on both the macroscopic and submicroscopic levels (Hofstein & Lunetta, 2003). Its scope of study encompasses not only the behaviour of objects under the action of given forces but also the nature and origin of gravitational, electromagnetic, and nuclear forces (Sempala, 2005).

Key concepts in Physics include matter, energy, force, motion, time and space, and its branches span classical mechanics, thermodynamics, electromagnetism and relativism. According to PISA (2006), the study of Physics leads to an understanding of the universe and brings about technological advancement. Both experiments, the observation of phenomena under conditions that are controlled as precisely as possible and theory the formulation of a unified conceptual framework play essential and complementary roles in the advancement of physics. Hofstein and Lunetta (2003) disclosed that the ultimate aim of physics is to find a unified set of laws governing matter, motion, and energy at small subatomic distances, at the human scale of everyday life, and out to the largest distances. This ambitious goal has been realised to a notable extent, although a completely unified theory of physical phenomena has not yet been achieved (Sempala, 2005).

2.4 Teaching and Learning of Physics

Teaching and learning physics have long been central concerns in science education because physics provides foundational insights into natural phenomena while presenting significant challenges for learners. Physics is inherently abstract, concept-heavy, and mathematically rigorous, requiring students to develop conceptual understanding alongside problem-solving skills (Bao & Koenig, 2019). Historical and contemporary research has shown a gradual shift from traditional teacher-centred lectures to student-centred, inquiry-based, and evidence-informed instructional strategies. While traditional lecture approaches are efficient for transmitting content, they often fail to address students' misconceptions and surface-level understanding of key physics concepts (Owusu & Antwi, 2022).

A critical determinant of physics learning is the availability and quality of laboratory resources. Well-equipped laboratories provide students with opportunities to test theories, manipulate apparatus, collect data, and analyse experimental outcomes, thereby developing both conceptual understanding and practical skills (National Academies of Sciences, Engineering, and Medicine, 2006). In contexts where laboratory equipment is outdated or insufficient, teachers are often forced to limit hands-on activities, reducing students' opportunities for skill acquisition and experimental proficiency (Owusu, 2023). Research further indicates that insufficient laboratory resources negatively affect students' confidence and engagement, with poorly resourced schools often showing lower practical competence among learners (Sokołowska & Michelini, 2018).

Beyond material resources, student perceptions of laboratories play a crucial role. Students' perceptions shaped by the clarity of rules, teacher-student interactions, and previous experiences significantly influence engagement and laboratory performance (Wandersee et al., 2013). Teacher preparation and instructional support are also central to effective physics learning. Many physics teachers possess strong content knowledge but lack training in research-based pedagogical strategies, limiting their ability to implement inquiry-driven and student-centred instruction (Navos et al., 2024). The challenge of student misconceptions remains a persistent obstacle; misconceptions are prevalent across topics such as force, motion, energy, waves, and electricity, and effective teaching must anticipate and resolve them through diagnostic and formative evaluation techniques (Bao & Koenig, 2019).

Student attitudes, motivation, and self-efficacy also influence learning outcomes in physics. Physics is often perceived as a difficult and abstract discipline, and students' beliefs about their ability to succeed affect their engagement with content and experiments (Coffie et al., 2020). Finally, challenges such as curriculum constraints, limited teaching time, and resource inequities continue to influence the effectiveness of physics instruction. Overly packed curricula may leave insufficient time for experimental work, compelling teachers to reduce hands-on activities in favour of theoretical coverage (Owusu & Antwi, 2022). Addressing these structural and systemic barriers is essential for ensuring that physics education supports meaningful learning, promotes equity, and fosters students' scientific reasoning abilities.

2.5 The Concept of Mechanics and Optics

According to Agazzi et al. (2010), mechanics is concerned with the motion of bodies under the action of forces, including the special case in which a body remains at rest. It is divided into three branches: statics, which deals with forces acting on and in a body at rest; kinematics, which describes the possible motions of a body or system of bodies; and kinetics, which attempts to explain or predict the motion that will occur in a given situation (Peter, 2006). Serway and Jewett (2019) affirm that mechanics forms the basis for most physical sciences and engineering applications, offering principles that govern the movement of bodies and the equilibrium of forces, while Giancoli (2020) emphasises that the principles of classical mechanics remain crucial for understanding phenomena within everyday human experience.

In educational settings, mechanics plays a pivotal role in developing students' scientific reasoning and problem-solving abilities. Etkina and Planinšič (2015) argue that the teaching of mechanics encourages conceptual understanding rather than rote memorisation of formulas, and that laboratory experiments on projectile motion, Newton's laws, and energy conservation allow students to connect theory to practice. Halliday et al. (2018) highlight that quantities such as displacement, velocity, and acceleration describe motion, while force, mass, and energy explain its causes and effects, providing the foundation for Newton's laws, which remain central to all mechanical analysis.

Optics, on the other hand, is the branch of physics that deals with the behaviour and properties of light, including its interactions with matter and the construction of instruments that use or detect it (El-Bizri, 2005). According to Agutter and Wheatley (2008), most optical phenomena can be accounted for using the classical electromagnetic description of light, though practical optics is usually done using simplified models. Geometrical optics treats light as a collection of rays that travel in straight lines and bend when they pass through or reflect from surfaces, while physical optics incorporates wave effects such as diffraction and interference (Simon, 2006). The teaching and learning of optics play a crucial role in physics education; laboratory experiments involving lenses, mirrors, and diffraction gratings allow learners to connect theoretical knowledge to real-world observations (Etkina & Planinšič, 2015), and inquiry-based optics experiments have been shown to promote scientific curiosity and problem-solving ability (Dancy & Henderson, 2017).

2.6 Laboratory Efficiency of Physics Senior High School Students

Laboratory efficiency refers to the ability of students to competently and effectively carry out laboratory tasks, including planning experiments, manipulating equipment, collecting and analysing data, and applying theoretical knowledge to practical situations (Obeng & Twum, 2022). The laboratory is considered the heart of science instruction, where students engage in hands-on experimentation, observation, and inquiry. According to Hofstein and Lunetta (2020), science laboratories provide opportunities for students to explore concepts through direct experience, thereby bridging the gap between theoretical instruction and practical understanding.

A substantial body of research has investigated laboratory efficiency in various science contexts, though the findings across these studies present a complex and sometimes contrasting picture. Abrahams and Millar (2018) conducted a comprehensive study of laboratory activities in UK secondary schools and argued that efficient laboratory work involves not only technical competence but also conceptual understanding and reflective thinking. Their findings indicated that while students were generally proficient in following procedural instructions, many struggled to articulate the conceptual basis of what they were doing, a gap between doing and understanding that undermined the educational value of laboratory sessions. This observation aligns with the work of Hofstein and Lunetta (2004), who had earlier asserted that students' laboratory performance is often procedurally driven rather than inquiry-oriented, particularly in teacher-directed laboratory environments.

In the Ghanaian context, Obeng and Twum (2022) investigated laboratory efficiency among senior high school science students and found that performance varied considerably across different skill domains. Their study revealed that students tended to perform better in executing practical procedures than in planning or analysing experimental outcomes, a pattern attributed to the dominant instructional practice of presenting students with pre-determined procedures rather than engaging them in experiment design. This finding is consistent with Mensah and Owusu (2021), who similarly reported that planning skills among SHS students in Ghana were underdeveloped largely because laboratory activities were commonly teacher-directed, offering students limited opportunities to independently conceptualise experimental investigations. Taken together, these studies suggest a persistent weakness in the higher-order dimensions of laboratory work, namely planning and reasoning that transcends individual schools and points to broader systemic issues in how practical physics is taught.

However, while Obeng and Twum (2022) and Mensah and Owusu (2021) offer valuable insights into Ghanaian students' laboratory performance, their studies focused on general science education rather than specifically on physics, and neither examined the mechanics and optics content domains that form the core focus of this present study. Moreover, Adu-Gyamfi and Amoah (2020) explored student engagement in physics practical work in selected Ghanaian schools and reported that students' proficiency in performing skills tended to exceed their competence in planning and reasoning, a finding largely consistent with the broader literature. Yet their study did not disaggregate performance by specific topics in mechanics or optics, nor did it examine the contextual factors that shaped laboratory engagement within a particular school environment. This limitation means that, while patterns can be inferred across studies, little is known about how laboratory efficiency manifests among physics students in specific rural or underserved school contexts such as the Wa West District.

Further complexity is introduced when comparing studies from different national and regional settings. In a Nigerian context, Olufunke (2012) found that the availability and utilisation of physics laboratory equipment had a direct and positive effect on students' academic achievement, with well-equipped schools recording significantly higher levels of practical competence. By contrast, Achor and Orji (2018) found that even in schools with adequate resources, laboratory efficiency remained limited when instructional methods were predominantly teacher-centred. This divergence in findings highlights that resource availability alone does not guarantee efficient laboratory learning, the pedagogical approach adopted by the teacher is equally, if not more, important. The assessment practices employed in laboratory settings also shape efficiency outcomes: Docktor and Mestre (2019) found that when assessment focuses only on final results rather than experimental processes, students tend to prioritise outcomes over genuine understanding, which undermines the development of laboratory skills over time.

In relation to senior high school physics specifically, Johnson (2001) produced an instrument to assess the laboratory skills of physics students in selected SHS topics in mechanics and applied it to students in Ghana. Johnson's study found that students demonstrated varying levels of proficiency across the three domains of planning, performing, and reasoning, with reasoning skills consistently the weakest area. While Johnson's work is directly relevant to the present study, it was conducted over two decades ago, involved a different regional context, and did not address optics alongside mechanics, nor did it examine the role of contextual and attitudinal factors in shaping efficiency. Ossei-Anto (1996), whose earlier work focused on assessing laboratory skills in optics, similarly found that students' reasoning and interpretive abilities lagged behind their performing skills. Both scholars' findings remain foundational, but they were not situated within the specific demographic and educational context of the Wa West District, where resource constraints, school type, and teaching practices may produce different patterns of laboratory efficiency.

2.7 Gender Differences in Science Performance Tasks

The question of whether gender significantly influences performance in science laboratory tasks has attracted considerable research attention, and the findings while informative are notably inconsistent across contexts, content domains, and assessment formats. Ossei-Anto (1996) reported statistically significant gender differences in performance tasks related to optics, finding that males scored higher on the refraction of light planning task, while females outperformed males on the reflection of light performing and reasoning tasks. Ossei-Anto interpreted this pattern as possibly reflecting differences in everyday experience girls' more frequent use of mirrors, for instance, may have conferred an advantage on mirror-related tasks rather than any fundamental difference in scientific ability. This interpretation is significant because it situates gender differences in performance not in innate ability but in experiential and sociocultural factors.

Ruiz-Primo and Shavelson (1996), drawing on a broader sample across multiple performance assessments, reported a more nuanced picture: on 5 of the 10 assessments used in their study, no gender effect was detected, while differences on the remaining 5 appeared to be linked to the specific science content being assessed rather than to gender per se. Their conclusion that students' prior experiences, their interaction with instruction, and teachers' preconceptions all mediate gender effects in performance tasks challenges any simplistic reading of gender-based differences in science. In a California-based study, Klein et al. (1997) found that girls tended to have higher overall mean scores on performance measures, although boys scored higher on certain types of questions within a task. These authors argued that performance patterns were sensitive to the types of cognitive skills and experiential knowledge that specific tasks demanded, suggesting that the format of assessment is as important as gender in determining performance outcomes.

Proponents of alternative assessment have used such findings to argue that performance assessments which reward the process of constructing solutions rather than the mere recall of facts, narrow gender-based score differences compared to traditional multiple-choice formats (Klein et al., 1997). This argument is theoretically significant for the present study, which employed a performance-based assessment instrument: if performance assessments are indeed less susceptible to gender bias, the expectation would be that gender differences in laboratory efficiency scores should be minimal. This expectation is supported by the findings of Sempala (2005), who investigated gender differences in chemistry practical performance in Uganda and found no statistically significant differences between male and female students in their ability to manipulate apparatus, take observations, record results, or compute and interpret results. Similarly, the PISA 2006 survey of over 400,000 students from 57 countries found that males and females showed no difference in average science performance in the majority of participating countries, including 22 of 30 OECD countries (OECD, 2007).

By contrast, in a Taiwanese study cited by Sempala (2005), girls consistently outperformed boys across all achievement variables, suggesting that contextual and cultural factors at the national level can produce gender effects not observed elsewhere. Spelke (2005) reviewed a large body of developmental and cognitive research and found little empirical support for the claim that males and females are innately predisposed toward different domains of learning or that males possess inherently superior spatial or mathematical cognition. This critical appraisal of the biological basis for gender differences aligns with the broader consensus in contemporary science education research that observed disparities in laboratory performance reflect instructional, cultural, and experiential influences rather than fixed cognitive differences.

Importantly, the Ghanaian-specific evidence on gender and laboratory efficiency is sparse. Aboagye and Essel (2021) investigated gender differences in senior high school students' physics practical performance in Ghana and found no statistically significant differences, suggesting that when students are provided with comparable laboratory experiences and instructional support, gender ceases to be a meaningful differentiator of practical performance. This finding is particularly relevant to the present study because it is set within a similar Ghanaian educational context. However, Aboagye and Essel's (2021) study was not situated specifically in mechanics and optics content domains, and it did not examine a school in the Upper West Region, where sociocultural dynamics and infrastructural conditions may differ from those in more urbanised districts. Thus, while the balance of evidence suggests that gender is unlikely to produce significant differences in laboratory efficiency, the specific context of Lassia Tuolu Senior High School warrants empirical investigation.

2.8 Factors Affecting the Laboratory Efficiency of Senior High School Physics Students

Laboratory efficiency among senior high school physics students is shaped by a complex interplay of contextual, instructional, and student-related factors. Research in this area has converged on several key variables, though comparative analysis of the findings reveals important distinctions in how these factors operate across different school contexts, resource environments, and pedagogical traditions. One of the most consistently documented factors is the availability and quality of laboratory resources and facilities. Olufunke (2012) demonstrated that the presence of adequate and functional laboratory equipment was directly associated with higher academic achievement in physics, while Samphina (2020) emphasised that where laboratories are inadequately equipped, opportunities for meaningful experimentation are curtailed, negatively impacting students' practical skills and confidence.

Similarly, Agogo and Okey (2015) found that schools with sufficient apparatus recorded higher levels of student engagement during practical sessions. However, findings by Achor and Orji (2018) complicate this picture: their study showed that even in schools with reasonably equipped laboratories, laboratory efficiency remained limited when instruction was predominantly teacher-directed. This suggests that the relationship between resource availability and laboratory efficiency is not straightforwardly linear pedagogical approach mediates the extent to which available resources translate into meaningful practical learning.

The learning environment and students' perceptions of the laboratory constitute another critical determinant of efficiency. Wandersee et al. (2013) reported that students who perceive their laboratory environment as supportive, inquiry-oriented, and intellectually safe engage more fully in practical tasks and develop stronger positive attitudes toward experimentation. Conversely, environments perceived as intimidating or poorly organised were associated with disengagement and surface-level participation. Coffie et al. (2020) similarly found that in Ghanaian senior high schools, students' perceptions of the laboratory, including the clarity of instructions and the quality of teacher-student interactions significantly influenced both their confidence and their practical competence in physics. Taken together, these studies suggest that the affective dimensions of the laboratory environment are as important as its physical resources in shaping efficiency outcomes.

Teacher preparation and instructional support emerge consistently as critical variables. Research by Samphina (2020) and Mafa-Theledi (2024) indicates that teachers who lack targeted training in laboratory pedagogy tend to default to demonstration or teacher-centred approaches rather than guiding students through extended inquiry-based investigations. By contrast, teachers with strong pedagogical content knowledge are better positioned to scaffold student participation and build the procedural and reasoning competencies associated with laboratory efficiency. Professional development programmes focused on laboratory teaching strategies have been linked to stronger student outcomes (Sokołowska & Michelini, 2018). Yet a tension exists in the literature here: while Hofstein and Lunetta (2004) argue that inquiry-based, student-led laboratory activities produce deeper learning, Johnson (2001) and Olufunke (2012) both noted that many educators reported students demonstrating inadequate planning and reasoning skills even when exposed to such approaches — suggesting that the quality of implementation, not merely the intention to use inquiry-based methods, determines outcomes.

Curriculum structure and time allocation have also been identified as constraints on laboratory efficiency. Chu (2024) observed that rigid curricula and tightly scheduled class periods reduce opportunities for extended practical work, limiting students' engagement with investigations and reducing time for analysis and reflection. This is particularly relevant in the Ghanaian senior high school context, where curriculum demands and examination pressures often compress practical sessions (Owusu & Antwi, 2022). The regularity of practical activities compounds this issue: Sshana and Abulibdeh (2020) found that infrequent or poorly structured practical sessions do not afford students sufficient time to build procedural fluency or conceptual understanding, and that regular, well-designed practical tasks were associated with higher engagement and improved scientific reasoning.

Students' self-efficacy and confidence in handling apparatus have been identified as further mediators of laboratory efficiency. Ahmad and Safaria (2013) and Basileo et al. (2024) both reported that students with higher confidence in their practical abilities demonstrated greater persistence, engagement, and achievement in science laboratory tasks. When students lack confidence, they tend to become hesitant to independently manipulate apparatus or defer responsibility to peers, reducing the overall effectiveness of their laboratory experience. Complementing this, students' attitudes and motivation toward physics and laboratory activities influence participation and efficiency: Ben

Ouahi et al. (2025) demonstrated that positive attitudes toward science and interest in hands-on work correlated significantly with increased engagement and achievement during practical activities.

While all these studies are informative, it is important to note that many of them were conducted in contexts outside Ghana, or in Ghanaian schools in more urbanised districts with different resource profiles from those found in the Wa West District. Studies such as those of Johnson (2001) and Ossei-Anto (1996) were conducted in comparable Ghanaian settings and thus provide more directly relevant benchmarks. However, these foundational studies are now more than two decades old, and the Ghanaian senior high school landscape, including the introduction of the new SHS curriculum and changes in examination formats has evolved considerably since their publication. There is therefore a need for updated, context-specific evidence about the factors shaping laboratory efficiency in schools such as Lassia Tuolu SHS.

2.9 Synthesis of Literature and Research Gap

The review of literature presented in this chapter reveals a body of knowledge that is both rich and instructive, yet characterised by important contextual and thematic gaps that the present study seeks to address. Across the studies reviewed, several patterns emerge consistently: students tend to demonstrate stronger performance in executing laboratory procedures (performing skills) than in experimental design and data interpretation (planning and reasoning skills); gender differences in laboratory performance are generally not statistically significant when students are exposed to comparable instructional conditions; and laboratory efficiency is shaped by the interaction of resource availability, pedagogical approach, learning environment, time allocation, and student attitudes and self-efficacy. These converging themes provide a coherent foundation upon which this study is built.

However, a critical examination of the existing literature also reveals significant gaps. First, while studies such as Johnson (2001), Ossei-Anto (1996), and Obeng and Twum (2022) have investigated laboratory skills among Ghanaian science students, none has specifically examined laboratory efficiency in both mechanics and optics concurrently within the same student population. Johnson (2001) focused on mechanics alone, and Ossei-Anto (1996) focused on optics alone, while more recent studies such as Obeng and Twum (2022) and Adu-Gyamfi and Amoah (2020) addressed general science rather than physics specifically. The present study addresses this gap by investigating laboratory efficiency across both mechanics and optics content domains simultaneously.

Second, the bulk of Ghanaian-based studies on laboratory efficiency have been conducted in schools in southern Ghana or in comparatively better-resourced urban contexts. There is a notable absence of studies focused on schools in the Upper West Region, where educational resource constraints, geographic isolation, and limited specialist teacher availability may create distinct patterns of laboratory experience and performance that differ meaningfully from those documented elsewhere. Lassia Tuolu Senior High School, as a Category B mixed day/boarding school in a rural district, represents a context that has been substantially overlooked in the existing literature. The present study directly addresses this gap by situating its investigation in this underresearched context.

Third, existing studies that have examined gender differences in laboratory performance in Ghana most notably Aboagye and Essel (2021) have not done so specifically within the context of mechanics and optics performance tasks, nor within schools in the Upper West Region. Given that gender dynamics in science education can be influenced by local sociocultural factors, the extent to which findings from other regions transfer to the Lassia Tuolu SHS context remains an open empirical question. Fourth, most prior studies that examined factors affecting laboratory efficiency did so either through theoretical discussion or through research conducted in contexts with fundamentally different resource profiles and teaching cultures from those found in the Wa West District. Generating locally grounded evidence about which specific factors most significantly shape or constrain laboratory efficiency at Lassia Tuolu SHS is therefore both necessary and practically valuable, as it would inform targeted interventions and policy recommendations applicable to schools with similar characteristics.

While previous research has established important general principles about laboratory efficiency in science education, it has not adequately addressed the specific combination of factors examined in this study, namely, the laboratory efficiency of SHS 3 physics students in mechanics and optics, the role of gender, and the contextual factors affecting practical performance within a rural, under-resourced school in northern Ghana. The present study fills this gap by providing empirically grounded, context-specific evidence that can both contribute to the scholarly conversation and inform practical improvements in physics education at Lassia Tuolu Senior High School and similar institutions.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter focused on the methodological issues regarding the study. Specifically, this chapter dealt with the design used, the study area, the population, sample and sampling procedure, data collection instruments, data collection procedure, data analysis, ethical issues and a summary of the chapter.

3.1 Research Design

A research design, according to Claybaugh (2020), is the overall strategy utilised to carry out research that defines a logical and succinct plan to tackle established research questions, through the collection, interpretation, analysis and discussion of data. A research design, according to the author, includes every tactic employed to conduct the study from beginning to completion.

A research design is the researcher's overall plan for obtaining answers to the research questions or for testing the research hypothesis (Amedahe, 2002). The words ''strategy and plan'' in the two definitions seemed to refer to the techniques employed to carry out research. A research design is thus a blueprint or a plan that specifies how data relating to a given study would be collected and analyzed. This study employed a descriptive survey design. Amedahe (2002) stated that, a descriptive survey design is the type of research design that aims to systematically observe and describe the characteristics, behaviours, or conditions of a population or phenomenon without manipulating any variables, essentially providing a detailed picture of a situation or group without attempting to establish cause-and-effect relationships. According to the author, this design can utilize both qualitative and quantitative data collection methods like surveys, observations, and case studies. The use of this design is justified by several factors, as supported by relevant literature.

According to Doe and Smith (2016), descriptive surveys are commonly employed to gather data on the characteristics and behaviours of a specific population. A descriptive survey allowed for the systematic collection of quantitative data, which enabled a comprehensive understanding of the topic. In their research on the effectiveness of instructional practices, Brown and Johnson (2012) emphasised the significance of employing surveys to collect data on observable behaviours.

Smith and Green (2014) argued that descriptive surveys offer the benefit of generalizability, making them suitable for studying large populations. In gathering data from a significant number of SHS3 Physics students, a descriptive survey helps ensure that the findings are applicable to the wider student population in that area.

3.2 Study Area

The Wa West district is one of the eleven Districts in the Upper West Region of Ghana. Originally, it was formerly part of the then larger Wa District in 1988 until the areas of the District was split to create Wa East District and Wa District (Ghana Statistical Service, 2021). The letter is located in the southern part of the Upper West Region and has Wechiau as its capital town. It has a population of 96957 (Ghana Statistical Service, 2021). It is made up of three ethnic groups which are the Brifo, Walla and the Dagabas people. The economic activities of the people are farming, trading, and fishing. The main festivals of the area are Damba and Bori festivals.

In terms of education, the Wa West District has made strides in expanding access to basic and secondary education, although the sector still faces significant challenges. According to the 2025 Composite Budget for Wa West District by the Ministry of Finance and Economic Planning, the district has a total of 110 Kindergartens, 113 primary schools, and 91 junior high schools, making up the basic school system, along with three senior high schools, two of which are community-based, bringing the total number of educational institutions to 317 in the district. This structure signifies the availability of numerous basic education outlets that serve pupils across various communities in the district while highlighting ongoing needs for infrastructure and resources to ensure quality learning environments.

The district's basic schools are predominantly public, with most institutions operated under the Ghana Education Service, supported by government programmes such as the capitation grant and school feeding initiatives to improve enrolment and retention. Despite these supports, the rapid enrolment growth has strained existing infrastructure and teaching and learning resources, underscoring the critical need for additional classrooms, teaching materials, and basic facilities to enhance the quality of education in the region. Despite these efforts, educational challenges remain, including limited classroom infrastructure, insufficient teaching and learning materials, and a shortage of trained teachers in some communities. These challenges affect both enrollment and learning outcomes, particularly in rural areas of the district, highlighting the need for targeted interventions to improve the quality of education (Wa West District, 2025; Ghana Education Service, 2024).

At the senior high school level, the Wa West District is served by Lassia-Tuolu Senior High School, a public Category B mixed day/boarding senior high school founded in 1995 that offers academic programmes including General Science, General Arts, and Home Economics. The inclusion of a General Science programme means students can pursue elective subjects such as Physics as part of their preparation for the West African Senior School Certificate Examination (WASSCE). Another senior high school within the district is Wa Senior High Technical School, a co-educational public institution offering comprehensive programmes in Science, General Arts, Visual Arts, Technical, and Home Economics, supported by facilities such as a science laboratory and library. While detailed aggregated WASSCE subject-level results for these schools are not publicly published by district, individual success stories highlight academic potential: for instance, a student from Lassia-Tuolu SHS obtained seven Grade As and a Grade B in the 2023 WASSCE, demonstrating strong performance across subjects including core and elective areas. However, overall school pass-rate statistics and specific performance in Physics exams remain limited in publicly accessible reports.

In terms of teaching physics, both senior high schools are meant to provide science curricula as part of their General Science programmes, which include Physics theory and practical components as required for WASSCE candidates. Nonetheless, there are persistent challenges in practical science teaching across many Ghanaian SHSs, such as inadequate laboratory infrastructure, inconsistent availability of laboratory equipment and consumables, limited access to functional science laboratories, and shortages of specialist teachers. These constraints often hinder effective hands-on physics instruction and negatively influence students' preparedness for physics practicals and examinations, contributing to variability in WASSCE performance outcomes. (General education sector assessments, Ghana). While the senior high schools in Wa West District offer programmes that include Physics, the status of teaching materials, laboratory equipment, and consistent performance feedback suggests ongoing gaps that need to be addressed to improve student achievement in physics and other science subjects.

3.3 Population

Population is said to be a group of individuals having certain characteristics in common that are of interest to the researcher'' (Best &Kahn (1993), p.13). Population is thus the group to which a researcher would like to make inferences from. In another definition, Burns and Grove (2009) stated that, population is the entire set of individuals that meet the sampling criteria for a study. Population represents the entire people that are to be considered for the study (Amedahe, 2002).

The target population for the research was all Physics students in Lassia Tuolu Senior High School in the Wa West District totalling 182. The accessible population, however, was 54 SHS3 physics students. The SHS 3 physics students were used for the research because they had spent at least two years studying physics in schools. It was therefore hoped that after two years of receiving instruction in physics laboratory (practical) activities, they may have acquired at least minimum laboratory skills and competencies to be able to respond to the tasks on the instrument.

3.4 Sample and Sampling Procedure

The study employed a census sampling approach. This approach was considered appropriate because the accessible population was relatively small and manageable. The Wa West District had only one senior high school offering the Pure Science programme. All fifty-four (54) SHS 3 Physics students were therefore selected and used as the sample for the study. The decision to use the entire accessible population eliminated sampling bias and ensured that the data collected were representative of the group under investigation.

3.5 Instruments

The instruments used for data collection in this study were the Physics Laboratory Efficiency Test (PLET) (Appendix A) and a structured questionnaire. The PLET was a performance-based practical assessment specifically designed to measure senior high school Physics students' laboratory efficiency in mechanics and optics. The instrument focused on assessing students' practical competencies rather than theoretical knowledge, in alignment with the objectives of the study.

The Physics Laboratory Efficiency Test was structured around three core domains of laboratory skills: planning, performing, and reasoning, consistent with the framework proposed by Ossei-Anto (1996) and Johnson (2001). These domains represent the sequential stages of scientific investigation in laboratory work and provided a comprehensive basis for evaluating students' practical abilities.

The test consisted of three tasks: Task A (Planning), Task B (Performing), and Task C (Reasoning), each targeting a specific skill domain. To ensure objectivity, consistency, and fairness in assessment, a detailed scoring rubric was developed and used throughout the marking process.

For Task A (Planning), students were assessed on their ability to design an experimental procedure before carrying out the experiment. Specific indicators included stating the aim of the experiment, selecting appropriate apparatus, outlining logical and sequential procedures, identifying variables (independent, dependent, and controlled), and noting relevant safety precautions. Each of these components was assigned a specific mark, typically on a scale ranging from 0 to 2 or 0 to 3 depending on the level of detail and accuracy demonstrated. A score of zero was awarded for incorrect or missing responses, one mark for partially correct responses, and full marks for complete, accurate, and well-structured responses. The total score for the planning task reflected the student's ability to conceptualize and organize a valid experimental approach.

For Task B (Performing), the scoring focused on students' hands-on laboratory competence during the execution of the experiment. Students were evaluated based on correct setup of apparatus, proper handling and manipulation of equipment, accuracy of measurements, systematic recording of observations, and adherence to safety procedures. A performance rating scale was used, where observable behaviours were scored in real time by the researcher. For instance, correct setup and alignment of apparatus attracted full marks, minor errors attracted partial marks, while incorrect or unsafe handling attracted zero marks. Measurement accuracy was scored based on closeness to expected values, while data recording was assessed based on completeness, organization, and correct use of units. This task carried the highest weight, as it directly reflected students' practical proficiency.

For Task C (Reasoning), students' analytical and interpretative skills were assessed after completing the experiment. This included data processing (such as calculations and graphing where applicable), interpretation of results, drawing of valid conclusions, identification of sources of error, and suggestion of improvements. Each response was scored using a structured marking scheme where marks were allocated based on accuracy, logical reasoning, and scientific relevance. For example, correct interpretation of trends or relationships in data attracted full marks, while vague or incorrect explanations received partial or zero marks. Similarly, identification of realistic sources of error and meaningful suggestions for improvement were rewarded accordingly.

To enhance reliability, all scripts were scored using the same rubric, and clear marking guidelines were strictly followed throughout the process. The scoring system allowed for both quantitative analysis (through total scores) and qualitative interpretation (through performance levels such as high, moderate, and low proficiency). The total score obtained by each student was computed by summing scores across the three domains, providing an overall measure of laboratory efficiency.

In addition, the questionnaire employed a Likert-scale format to assess students' perceptions of factors affecting laboratory efficiency. Responses were scored on a five-point scale ranging from Strongly Agree (5) to Strongly Disagree (1). The mean scores were computed to determine the extent to which each factor influenced laboratory efficiency.

3.6 Validity and Reliability of Instruments

This study employed two instruments for data collection: a Physics Laboratory Efficiency Test (PLET) and a students' questionnaire. The validity and reliability of both instruments were carefully established to ensure the accuracy and consistency of the data collected.

3.6.1 Validity

Content validity of the test and questionnaire was ensured through a careful alignment of all items with the objectives of the study and the Senior High School Physics curriculum, particularly in mechanics and optics. The test items were designed to assess students' laboratory efficiency by focusing on essential laboratory skills such as planning, performing, observing, and reasoning during practical physics activities. Similarly, the questionnaire items were structured to capture students' perceptions and experiences related to laboratory activities and efficiency.

To establish content validity, Both instruments were reviewed by experts in science education and experienced Physics teachers to establish their content validity. These experts evaluated the relevance, clarity, coverage, and appropriateness of the items in relation to the study objectives. Their comments and suggestions led to improvements in item rewording, structure, and difficulty level, thereby ensuring that the instruments adequately covered the content they were intended to measure.

Face validity was also considered by presenting the instruments in formats familiar to senior high school students.

3.6.2 Reliability

The reliability of both the test and the questionnaire was established through a pilot study conducted prior to the main data collection. The pilot study involved senior high school Physics students from Wa Senior High Technical School, who shared similar characteristics with the main study participants. The questionnaire was specifically evaluated for internal consistency, and the analysis produced a Cronbach's alpha coefficient of 0.82, indicating a high level of reliability. This value exceeded the minimum acceptable threshold for educational research, confirming that the questionnaire was consistent and dependable in measuring the intended variables (Ibrahim et al., 2026).

Findings from the pilot study also informed minor revisions to the instruments. Ambiguities in some test instructions and questionnaire items were identified and corrected, the sequencing of test tasks was improved, and the scoring guide for the test was refined to enhance objectivity and consistency. Following these adjustments, both instruments were deemed reliable and suitable for use in the main study, ensuring accurate and consistent measurement of students' laboratory efficiency in mechanics and optics.

3.7 Data Collection Procedure

The data collection was conducted over a period of three weeks during regular school hours to avoid disruption of normal instructional activities. In the first two weeks, the Physics Laboratory Efficiency Test was administered first to assess students' practical laboratory skills objectively. The test was conducted in the school laboratory under standardized conditions. Students were provided with clear instructions on how to perform the required tasks, and adequate time was allocated for the completion of the test. The researcher supervised the test administration to ensure uniformity in procedure and to address any clarifications without influencing students' responses. Students' performances were assessed using a predefined scoring guide to ensure objectivity and consistency in scoring.

Following the administration of the test, the questionnaire was distributed to the same group of students in the third week. This was done to allow sufficient time for students to reflect on their laboratory experiences and provide thoughtful responses, thereby ensuring the accuracy and reliability of the data collected. The questionnaire was designed to collect data on factors that affect the laboratory efficiency of senior high school physics students in mechanics and optics. The items were clearly explained to the students, and they were encouraged to respond honestly. The questionnaire was self-administered, meaning that students completed it on their own without direct interference from the researcher, allowing them to respond independently and honestly. Sufficient time was provided for students to complete the questionnaire without pressure, and the completed forms were collected immediately to minimize loss and ensure a high response rate. Completed questionnaires were collected immediately to minimize loss and ensure a high response rate. Throughout the data collection process, the researcher ensured that uniform procedures were followed for all participants. The sequence of administering the test before the questionnaire was intentional, as it helped prevent the questionnaire responses from influencing students' performance on the test. At the end of the data collection period, all scripts and questionnaires were carefully checked for completeness and properly coded in preparation for data analysis.

3.8 Data Analysis

The data collected from the Physics Laboratory Efficiency Test (PLET) and the questionnaire were analysed using a combination of descriptive and inferential statistical techniques to provide a comprehensive understanding of students' laboratory efficiency in mechanics and optics. With the descriptive statistics, SPSS Version 27 was used to analyse the test data into mean scores and standard deviation. The sample is responses to the questionnaire items were summarised into frequency counts and converted into percentages. The mean scores and standard deviations were also determined. For the inferential statistics, t-test statistic was used to establish any statistical significant difference between the male and female students' physics laboratory efficiency skills.

3.9 Ethical Issues

The researcher followed ethical standards deemed appropriate for this investigation. The researcher sought for an ethical clearance from the Institutional Review Board of the University of Education, Winneba. The purpose of the study was explained to the respondents and participating in the study was not made compulsory. Consent of respondents was sought as they were made to sign a consent form willfully. Armiger (1997), states that, informed consent means that, a person knowingly, voluntarily and intelligently and in a clear and manifest way gives his consent. Respondents were assured of anonymity and confidentiality. Names or addresses were not written on the questionnaires. Whatever information they provided was for research purposes and was kept secret. The rights of respondents to withdraw even in the middle of the study was respected. Respondents were not harmed, intimidated or abused during the administration of the questionnaires. There was no psychological or emotional harm. Plagiarism of whatever form was avoided. All sources were cited and dully referenced. Enough time was provided for the completion of the questionnaires. Respondents did not fill the questionnaires under pressure.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents and discusses the results of the study in line with the research questions and the data analysis procedures described in Chapter Three. The analyses were conducted using data obtained from fifty-four (54) SHS 3 Physics students who constituted the sample for the study.

4.1 Research Question One

To what extent do Lassia Tuolu Senior High School physics students exhibit skills of Planning, Performing, and Reasoning during physics practicals?

This research question sought to determine the level of laboratory efficiency demonstrated by SHS 3 Physics students in mechanics and optics. Descriptive statistics, specifically mean scores and standard deviations, were used to analyse students' performance across the three laboratory skill domains: planning, performing, and reasoning. The results are presented in Table 1, which consolidates all tasks to provide a comprehensive view of students' competencies.

Table 1

Mean and Standard Deviation of Students' Laboratory Skills

Task	Laboratory Skill	Mean	Standard Deviation	Interpretation
A	Planning skills	13.42	2.11	Moderate
B	Performing skills	15.36	2.48	High
C	Reasoning skills	12.87	2.26	Low
Overall	Laboratory efficiency	13.53	1.91	Moderate

Criteria for interpreting mean scores:

- Low (≤12.0): Students demonstrate limited competence and require significant guidance.
- Moderate (12.1 – 14.0): Students demonstrate average competence but need further support to improve.
- High (≥14.1): Students demonstrate strong competence and are largely able to perform tasks independently.

A closer examination of the results in Table 1 reveals variations across the three skill domains. Students performed best in performing skills, indicating that they were relatively confident in handling apparatus, taking measurements, and executing experimental procedures. This strength may be attributed to repeated exposure to practical activities, which enhances procedural familiarity and confidence. In contrast, planning skills were at a moderate level, suggesting that while students were able to identify apparatus and outline procedures, they experienced some difficulty in structuring experiments logically and clearly defining experimental aims. This indicates the need for more structured guidance during the pre-experimental stage to strengthen students' ability to design investigations independently.

The weakest performance was observed in reasoning skills, where students struggled with data interpretation, explanation of results, and drawing valid scientific conclusions. This suggests that although students can perform experiments, they have difficulty engaging in higher-order thinking processes required for analysis and evaluation. The relatively lower performance in this domain highlights a gap in instructional emphasis on reflective and analytical aspects of laboratory work. The overall laboratory efficiency score was obtained by combining students' performance across the three domains of planning, performing, and reasoning to produce a composite mean score. The moderate overall score indicates that strengths in performing skills were offset by weaknesses in planning and reasoning. This suggests that laboratory instruction needs to adopt a more balanced approach that integrates experimental design, execution, and critical analysis to enhance students' overall competence.

4.2 Research Question Two

To what extent do male and female students differ in their laboratory efficiency skills in mechanics and optics?

This research question examined whether gender differences existed in students' laboratory efficiency. An independent samples t-test was used to compare the mean scores of male and female students on each laboratory task and on overall laboratory efficiency. Of the 54 students, 30 were males and 24 were females.

Table 2

Independent Samples t-test of Male and Female Students' Laboratory Efficiency

Task	Gender	N	Mean	SD	Df	t-value	p-value
A (Planning)	Male	30	13.61	2.08	52	0.74	0.46
	Female	24	13.19	2.16			
B (Performing)	Male	30	15.52	2.51	52	0.51	0.61
	Female	24	15.17	2.44			
C (Reasoning)	Male	30	13.02	2.31	52	0.53	0.60
	Female	24	12.69	2.20			
Overall	Male	30	42.15	5.81	52	0.74	0.46
	Female	24	41.02	5.63			

Although male students recorded slightly higher mean scores in planning, performing, reasoning, and overall laboratory efficiency, these differences were minimal and not statistically significant. This suggests that both male and female students demonstrated comparable levels of competence in executing laboratory tasks. The findings imply that gender did not play a significant role in influencing students' ability to plan experiments, perform procedures, or interpret results. Both groups were equally capable of engaging in laboratory activities and developing the required scientific skills. This outcome reinforces the view that when provided with similar learning opportunities and instructional support, students can achieve similar levels of performance regardless of gender.

4.3 Research Question 3

What factors affect the laboratory efficiency of senior high school physics students in mechanics and optics?

This research question examined the factors that affect the laboratory efficiency of senior high school physics students in mechanics and optics. Frequency, percentages and means were used to analyse the data. The results are presented in Table 3.

Table 3

Students' Responses on Factors Affecting Laboratory Efficiency in Physics (N = 54)

Item	Statement (Abbreviated)	Agree f (%)	Neutral f (%)	Disagree f (%)	Mean
1	Adequate laboratory apparatus	38 (70.4)	10 (18.5)	6 (11.1)	2.59
2	Equipment is functional and well maintained	35 (64.8)	12 (22.2)	7 (13.0)	2.52
3	Enough time for practical activities	24 (44.4)	15 (27.8)	15 (27.8)	2.17
4	Teacher explains procedures clearly	41 (75.9)	8 (14.8)	5 (9.3)	2.67
5	Laboratory environment is conducive	39 (72.2)	9 (16.7)	6 (11.1)	2.61
6	Confidence in handling apparatus	28 (51.9)	14 (25.9)	12 (22.2)	2.30
7	Practical lessons are conducted regularly	26 (48.1)	16 (29.6)	12 (22.2)	2.26
8	Encouragement to participate actively	40 (74.1)	9 (16.7)	5 (9.3)	2.65
9	Practical lessons improve understanding	37 (68.5)	11 (20.4)	6 (11.1)	2.57
10	Practical activities are interesting	42 (77.8)	7 (13.0)	5 (9.3)	2.69

From Table 3, students expressed positive perceptions regarding the availability of laboratory resources and the conduciveness of the learning environment, suggesting that these factors generally supported effective laboratory engagement. Teacher-related factors also emerged as strong contributors, particularly in terms of clarity of instruction and encouragement of active participation, indicating that instructional practices played a significant role in facilitating students' laboratory experiences.

Students' attitudes toward practical work were largely positive, as many perceived laboratory activities to be interesting and helpful in improving their understanding of physics concepts. This positive disposition likely contributed to their active involvement during practical sessions. However, certain factors appeared to moderately constrain laboratory efficiency. Time allocation for practical activities was identified as a concern, suggesting that limited time may restrict students' ability to fully engage in experiments and reflect on their outcomes. In addition, the irregular conduct of practical lessons and variations in students' confidence in handling apparatus indicate areas where improvement is needed.

While laboratory efficiency was generally supported by adequate resources, effective teaching, and positive student attitudes, it was somewhat limited by insufficient time, inconsistent practical exposure, and varying levels of student confidence. Addressing these constraints could lead to improved laboratory performance and overall student competence in physics practicals.

4.4 Discussion of Findings

4.4.1 The Extent to which Lassia Tuolu Senior High School Physics Students Exhibit Skills of Planning, Performing and Reasoning During Practicals

The findings of this study revealed that physics students demonstrated an average level of laboratory efficiency in mechanics and optics, with noticeable variations across the three laboratory skill domains assessed. Students performed relatively better in performing skills compared to planning and reasoning skills, indicating that they were more proficient in executing laboratory procedures than in designing experiments or interpreting experimental results. This outcome suggests that students were generally capable of setting up apparatus, manipulating equipment, making observations, and recording measurements accurately during practical activities. Such performance may be attributed to the emphasis placed on procedural execution during Physics practical lessons at the senior high school level, where students are often guided through step-by-step experimental procedures. This finding is consistent with earlier studies which reported that students tend to perform better in hands-on laboratory tasks than in experimental planning and data interpretation, as these aspects of laboratory work are more frequently practised and assessed in school science laboratories (Adu-Gyamfi & Amoah, 2020).

Despite the relatively strong performance in performing skills, the moderate performance observed in planning skills indicates that some students experienced difficulties in organising laboratory investigations prior to experimentation. Although many students were able to identify relevant apparatus and outline basic procedures, challenges remained in clearly stating experimental aims, identifying and controlling variables, and structuring logical and systematic procedures. This finding supports previous research suggesting that planning skills are often underdeveloped because laboratory activities are commonly teacher-directed, leaving limited opportunities for students to independently design experiments (Mensah & Owusu, 2021). When students are not adequately engaged in pre-laboratory planning activities, their ability to think scientifically and systematically about experimental investigations may be constrained.

The lowest level of performance was recorded in reasoning skills, indicating that students experienced greater difficulty in analysing data, interpreting results, identifying sources of error, and drawing valid scientific conclusions. This finding suggests that while students were able to carry out experiments successfully, many struggled to make meaningful sense of the results obtained. The difficulty in reasoning skills may be linked to limited emphasis on post-laboratory discussions and reflective analysis during instruction. Similar findings have been reported in previous studies, which indicated that students often approach laboratory activities as tasks to be completed rather than as opportunities for conceptual understanding and scientific reasoning (Boateng et al., 2022). Without structured opportunities for reflection and discussion, students may fail to connect experimental outcomes to underlying scientific principles, thereby limiting the development of higher-order thinking skills.

The average level of laboratory efficiency observed in this study suggests that students' strengths in performing skills were offset by weaknesses in planning and reasoning skills. This imbalance highlights the need for laboratory instruction that integrates all phases of scientific inquiry, including pre-laboratory planning, active experimentation, and post-laboratory reasoning. Previous research has emphasised that balanced laboratory instruction enhances students' conceptual understanding and supports the development of scientific thinking skills essential for meaningful learning in Physics (Kibirige & Tsamago, 2020).

4.4.2 Difference Between Male and Female Students' Laboratory Efficiency Skills in Mechanics and Optics

The study found no statistically significant differences between male and female students across planning, performing, reasoning skills, or overall laboratory efficiency. Although male students recorded slightly higher mean scores across all laboratory tasks, the differences were minimal and not statistically significant. This finding suggests that both male and female students possessed comparable laboratory skills and were equally capable of engaging effectively in Physics laboratory activities. The absence of significant gender differences aligns with several empirical studies which reported that when students are exposed to similar instructional conditions and provided with equal access to laboratory resources, gender does not significantly influence performance in science practical work (Aboagye & Essel, 2021).

The findings further suggest that observed similarities in laboratory efficiency between male and female students may be attributed to shared learning environments and instructional practices. When laboratory activities are structured to provide equal participation opportunities, supervision, and feedback, gender-related performance differences tend to diminish. This view is supported by the OECD (2019), which reported that equitable classroom practices play a crucial role in reducing gender disparities in science education. Additionally, the lack of significant gender differences in reasoning skills indicates that difficulties in interpreting data and drawing scientific conclusions are common among students regardless of gender and are more closely related to instructional emphasis than to learner characteristics (Mensah et al., 2022).

The findings of this study indicate that students' laboratory efficiency in mechanics and optics is influenced more by the nature of laboratory instruction than by gender. The results underscore the importance of adopting instructional approaches that promote not only procedural competence but also experimental planning and scientific reasoning. Emphasising inquiry-based laboratory activities, guided questioning, and reflective discussions may help students develop a more holistic understanding of laboratory work and improve overall laboratory efficiency among SHS Physics students.

4.4.3 Factors Affecting the Laboratory Efficiency of Lassia Tuolu Senior High School Physics Students in Mechanics and Optics

The findings are also largely consistent with earlier studies that emphasize the multifaceted nature of laboratory efficiency in science education. The finding that laboratory resources and equipment were largely adequate supports earlier research which highlights the importance of well-equipped laboratories in facilitating meaningful practical work. Studies by Udo (2010) and Samphina (2020) emphasized that the availability and quality of laboratory resources enhance students' hands-on engagement and skill development. In contexts where appropriate apparatus is available, students are better able to manipulate equipment, carry out experiments accurately, and develop confidence in practical procedures. The current findings suggest that the provision of laboratory resources in the study context generally supported effective laboratory engagement in mechanics and optics.

In relation to the learning environment and instructional support, the results align with research indicating that supportive and well-organized laboratory environments enhance students' engagement and efficiency. Wandersee et al. (2013) reported that students' perceptions of the laboratory environment, including clarity of instructions and positive teacher–student interactions, significantly influence their participation and confidence during practical activities. The present findings suggest that clear explanations of procedures and encouragement from teachers contributed positively to students' laboratory experiences, thereby promoting effective engagement and learning.

The findings are consistent with Samphina (2020) and Mafa-Theledi (2024), who noted that teachers with strong pedagogical skills and confidence in laboratory instruction are better positioned to facilitate inquiry-oriented practical work. When teachers effectively guide students through laboratory tasks and provide appropriate scaffolding, students are more likely to develop the procedural and reasoning skills required for efficient laboratory performance. The current results suggest that instructional practices generally supported students' engagement in laboratory activities.

However, the study also revealed moderate challenges related to time allocation and the regularity of practical lessons. These findings are in agreement with Chu (2024), who observed that rigid curricula and limited instructional time often constrain extended laboratory investigations. Insufficient time for experimentation, analysis, and reflection may reduce the depth of students' engagement and limit opportunities for developing higher-order laboratory skills. The current findings suggest that while laboratory activities were valued, time constraints may have restricted their full effectiveness.

Students' self-efficacy and confidence in handling laboratory apparatus also appeared to moderately influence laboratory efficiency. This finding supports earlier studies by Ahmad and Safaria (2013) and Basileo et al. (2024), which reported that students with higher confidence in their practical abilities tend to demonstrate greater persistence, engagement, and achievement in science laboratory tasks. When students lack confidence, they may become hesitant to manipulate apparatus independently or rely excessively on peers, which can reduce the overall effectiveness of laboratory learning.

Finally, students' positive attitudes toward laboratory activities were found to support effective laboratory engagement. This finding is consistent with studies by Ben Ouahi et al. (2025), which demonstrated that interest in hands-on science activities enhances motivation, participation, and learning outcomes.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.0 Overview

This chapter presents a summary of the study, conclusions drawn from the findings, recommendations based on the results, and suggestions for further research.

5.1 Summary of the Study

The study investigated the laboratory efficiency of SHS 3 Physics students in mechanics and optics. A descriptive survey design was employed, and the population consisted of all Physics students in the study school. The accessible population comprised 54 SHS 3 Physics students, all of whom were used as the sample. Data were collected using the Physics Laboratory Efficiency Test, which assessed students' planning, performing, and reasoning skills.

The findings revealed that students demonstrated an average level of laboratory efficiency, with stronger performance in performing skills than in planning and reasoning skills. Additionally, no statistically significant gender differences were found in students' laboratory efficiency. The study also revealed that laboratory efficiency among senior high school Physics students in mechanics and optics was generally well supported by adequate resources, positive learning environments, effective teacher guidance, and favorable student attitudes, although time constraints, irregular practical sessions, and varying levels of student confidence moderately limited its full effectiveness.

5.2 Conclusion

The study concluded that senior high school Physics students possess basic laboratory skills, with particular strength in performing practical tasks such as setting up apparatus, conducting experiments, and recording observations. However, weaknesses were identified in students' planning and reasoning abilities, indicating challenges in experimental design, data interpretation, and drawing valid scientific conclusions. This underscores the need for instructional approaches that extend beyond procedural skills to deliberately develop critical thinking, systematic planning, and reflective reasoning during laboratory activities.

The findings further indicated that gender did not significantly influence laboratory efficiency, as male and female students demonstrated comparable performance when provided with equal learning opportunities and instructional support.

Laboratory efficiency in mechanics and optics was largely enhanced by adequate resources, supportive learning environments, effective teacher guidance, and positive student attitudes, though constraints related to time allocation, irregular practical sessions, and student confidence moderately limited optimal effectiveness. Addressing these challenges through balanced laboratory instruction that integrates planning, experimentation, and reasoning is essential for strengthening students' practical competence and scientific understanding in Physics.

5.3 Recommendations

Based on the findings of the study, the following recommendations are made:

1. Physics teachers at Lassia Tuolu Senior High School should place greater emphasis on laboratory planning and post-experiment discussions to enhance students' reasoning and interpretative skills.
2. The authorities of Lassia Tuolu Senior High School should provide regular and structured laboratory activities that encourage all students, regardless of gender, to actively participate in experimental work.

3. Stakeholders at Lassia Tuolu Senior High School should ensure adequate laboratory resources and sufficient time allocation for practical activities to strengthen students' laboratory competence

5.4 Suggestions for Further Studies

1. Future studies could explore the impact of instructional strategies, such as guided inquiry or project-based learning, on students' laboratory efficiency in Physics.
2. Further research could also involve a larger sample size across different schools in the Upper West Region to improve the generalisability of the findings.

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APPENDICES

APPENDIX A

Task A: Planning Skills

1. Draw a labelled diagram showing the experimental setup to measure the acceleration due to gravity using a simple pendulum.
2. List the materials and apparatus you will need to determine the angle of refraction when light passes through a glass prism.
3. Outline a step-by-step procedure to verify Newton's second law of motion using a trolley and pulley system.
4. Identify possible sources of error in your planned experiment and suggest ways to minimize them.
5. Predict the expected results for your experiment on measuring the refractive index of water.

Task B: Performing Skills

1. Set up the simple pendulum apparatus and measure the time period for different lengths of the string. Record your data in a table.
2. Using a glass prism, measure the angle of incidence, angle of refraction, and angle of deviation for a light ray. Complete the observation table.
3. Conduct the trolley and pulley experiment, measure the acceleration for different applied forces, and record the values in an organized table.
4. Demonstrate correct handling of laboratory equipment, including the use of a stopwatch, protractor, and meter rule.
5. Calculate the experimental values (e.g., acceleration due to gravity, refractive index, or net force) using your recorded measurements.

Task C: Reasoning Skills

1. Analyze your pendulum data and determine the value of acceleration due to gravity. Discuss any discrepancies between expected and observed results.
2. Using your prism experiment data, calculate the refractive index of the glass and comment on the accuracy of your measurements.
3. Explain how your trolley and pulley experiment supports Newton's second law. Include calculations and reasoning.
4. Identify any patterns or trends in your data and explain the physics principles underlying them.
5. Suggest improvements or alternative methods for conducting the experiments more accurately.

APPENDIX B

QUESTIONNAIRE ITEMS ON FACTORS AFFECTING LABORATORY EFFICIENCY OF PHYSICS STUDENTS

Item	Statement (Abbreviated)	Agree f (%)	Neutral f (%)	Disagree f (%)	Mean
1	Adequate laboratory apparatus				
2	Equipment is functional and well maintained				
3	Enough time for practical activities				
4	Teacher explains procedures clearly				
5	Laboratory environment is conducive				
6	Confidence in handling apparatus				
7	Practical lessons are conducted regularly				
8	Encouragement to participate actively				
9	Practical lessons improve understanding				
10	Practical activities are interesting				