UNIVERSITY OF EDUCATION, WINNEBA

IMPROVING STUDENTS’ SCIENCE PROCESS SKILLS IN SELECTED TOPICS IN OPTICS THROUGH FREQUENT LABORATORY PRACTICAL ACTIVITIES

FESTUS KOFI BONI

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FESTUS KOFI BONI
(8241610006)

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UNIVERSITY OF EDUCATION, WINNEBA

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DECLARATION

Student's Declaration

I, **FESTUS KOFI BONI**, declare that this dissertation, with the exception of quotation and reference 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: ……………………………………….

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this dissertation was supervised in accordance with the guidelines for supervision of dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: DR. I. K. ANDERSON

SIGNATURE: ……………………………

DATE: ………………………………….

DEDICATION

I dedicate this academic work to my wife, Beatrice Annor and children, Thelma Kisseh Boni, Martin Kwasi Boni and Jeff Agbo Boni, for their patience and their source of encouragement, I say God bless you.

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ABSTRACT

This study examined the effect of frequent laboratory practical activities on students' acquisition of science process skills in selected topics in optics and also explored students' perceptions of these activities. The research adopted an action research design and involved 53 second-year physics students from Begoro Presbyterian Senior High School in the Eastern Region of Ghana. Data for the study were collected through personal observations, a checklist, and a closed-ended questionnaire. The study was carried out in three phases. In the first phase, a pre-intervention exercise was administered to determine the students' initial level of science process skills and to prepare them for the intervention activities. The second phase consisted of four weeks of weekly laboratory practical exercises, after which a post-test was conducted to assess the effect of the intervention on students' acquisition of science process skills. In the third phase, questionnaires were administered to gather students' views on the frequent laboratory practical activities. Both qualitative and quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel 2010. Pearson's correlation analysis was employed to examine the relationship between students' pre-intervention and post-intervention performance. The results revealed a very strong positive correlation (r = 0.987), indicating a substantial improvement in students' science process skills following consistent participation in laboratory practical activities. The findings further showed that frequent practical activities enhanced students' ability to manipulate laboratory equipment, follow correct procedures, label diagrams appropriately, read measuring instruments accurately, take precise measurements, plot graphs, analyse experimental data, and interpret results. These skills improved progressively as students continued to engage in practical activities. Students' perceptions of the frequent laboratory practical activities were generally positive, with mean scores exceeding the 2.5 benchmark across all questionnaire items. Students indicated that regular hands-on activities improved their observational accuracy, experimental design skills, inferential reasoning, and ability to communicate scientific findings effectively. The study therefore concludes that frequent laboratory practical activities significantly enhance students' acquisition of science process skills and can contribute to improved academic performance. Based on these findings, it is recommended that physics teachers consistently incorporate laboratory practical activities into their teaching to promote the development of essential science process skills.

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CHAPTER ONE

INTRODUCTION

1.0 Overview

This introductory chapter presents the background of the study and discusses the motivation for the study. The statement of the problem that needs to be researched follows it. The purpose for which the study is conducted, as well as the objectives that guide the study and the research questions that the study seeks to answer, are also presented in this chapter. Beneficiary to the outcome of the study that makes the study significant is discussed here. The scope that delimits the study is mentioned here. The likely conditions that may go beyond the control of the researcher and hence limit the generalisation of the findings to the study area are discussed in this chapter.

1.1 Background to the Study

The acquisition of science process skills by senior high school physics students is critical to meaningful science education (Akinbobola & Bada, 2022). These skills are best developed through frequent laboratory practical activities in areas such as mechanics, optics, heat, and electricity. However, in this study, students' science process skills were examined specifically through practical activities in some selected topics in optics. Optics is a branch of physics that deals with the behaviour and properties of light and its interaction with matter (Lipson, 2020). Despite its importance, optics is one of the topics that students frequently find challenging (Xu et al., 2021). Students struggle with optics because many concepts, such as refraction, image formation, focal length, and lens equations, are abstract and require strong spatial reasoning, mathematical manipulation, and precise observations. Optics activities involving lenses, mirrors, and ray diagrams require careful measurement, alignment of apparatus, and interpretation of light paths, which many students are not adequately trained to perform (Carson, 2011). This makes optics an ideal area to investigate how frequent laboratory practical activities influence students' acquisition of science process skills, which are essential in preparing learners for STEM fields (Bybee, 2010). Although several studies emphasize the importance of science process skills, there is limited literature specifically addressing how these skills are assessed within optics. A review of available studies shows that researchers have focused more on general science process skills in biology or chemistry (Fadzil & Saat, 2013; Hodosyova et al., 2015) with very few assessment frameworks tailored to optics experiments such as refraction, image formation, and lens manipulation. This lack of optics-specific assessment tools, methods, or validated instruments represents a clear research gap that this study seeks to address. Therefore, the claim of limited literature is supported by the absence of studies that operationally define or measure process skills in optics contexts at the senior high school level.

This study is grounded in constructivist learning theory, which states that students construct their own knowledge when provided with opportunities to interact with materials, explore phenomena, and reflect on observations (Driver & Bell as cited in Gijbels et al., 2006). Optics experiments naturally create such environments. Science plays a major role in national development because it is both a process and a product. When scientific procedures are poorly executed, students fail to develop the necessary skills to solve societal problems (Johnson, 2017). Issues such as environmental pollution, poor waste disposal, and the spread of vector-borne diseases require scientific reasoning and investigative skills. Kelly (as cited in Johnson, 2017) notes that science education should equip students with critical thinking, problem-solving abilities, and inquiry skills.

Unfortunately, Johnson (2017) reports that many science classrooms remain teacher-centred, with students passively receiving information. Teachers often rely on lectures, note dictation, and textbook reading instead of engaging students in hands-on investigations. This contributes to the low acquisition of science process skills among students, which is the central problem addressed by this study**.** For Ghana to achieve scientific and technological development, students must be given opportunities to engage in practical work that strengthens these skills.

The Senior High School Physics syllabus recommends a balance of theory and practical activities, allocating four periods to theory and two to practical work per week (Ministry of Education, 2010). The syllabus emphasizes that practical activities help students connect school physics to real-world applications and enhance interest in the subject. However, research shows that many physics teachers prioritize theory over laboratory activities (Hofstein & Mamlok-Naaman, 2007). Factors such as large class sizes, limited resources, inadequate laboratory equipment, and time constraints further limit practical work (Windschitl, 2003; Hume & Coll, 2008). As a result, practical activities in optics are either rushed through, poorly executed, or omitted entirely**.**

This deprives students of hands-on experiences necessary for conceptual understanding and skill development, reducing their motivation and interest in physics (Abd-El-Khalick & Lederman, 2000). Ibiyengibo, as cited in DeBoer (2019), argues that many secondary school laboratories lack adequate equipment, making it difficult for students to experience authentic scientific inquiry.

The physics syllabus (MOE, 2010) identifies essential science process skills such as observation, planning, experimentation, manipulation of equipment, measurement, recording, interpretation, and communication. These align with Ajaja (2010), who notes that these skills form the foundation of scientific inquiry and knowledge creation. In this study, the focus is on experimenting, observing, inferring, measuring, and communicating.

Practical activities have consistently been shown to develop these skills. They enhance conceptual understanding, increase motivation, and strengthen higher-order thinking (McFarlane & Sakellariou, 2002). Fadzil and Saat (2013) and Schwichow et al. (2016) found that practical work supports the acquisition of scientific knowledge and science process skills. Roberts (as cited in Shana & Abulibdeh, 2020) notes that students learn effectively when they explore and experiment independently.

Despite these benefits, students in many SHS physics classrooms still have limited opportunities for frequent optics practical activities (Etkina et al., 2010). This leads to weak process skill development and poor ability to apply concepts (Bigozzi et al., 2018). The National Research Council (2000) warns that without consistent practical experience, students struggle to think critically and solve scientific problems.

Therefore, the specific problem addressed by this study is that limited engagement in optics laboratory activities contributes to low acquisition of science process skills among SHS physics students. This study seeks to examine how frequent practical activities in optics improve students' acquisition of these essential skills, providing empirical evidence to improve teaching, learning, and policy implementation in physics education.

1.2 Statement of the Problem

The effective teaching of physics at the senior high school level, particularly in selected topics in optics, requires adequate allocation of time for laboratory practical activities to improve students' science process skills, as stipulated in the Senior High School Physics Syllabus (Ministry of Education , 2010). However, in many senior high schools within the Fanteakwa District of the Eastern Region, the specific setting of this study, laboratory periods are not consistently scheduled on official school timetables. This concern is supported by national reports indicating that Ghanaian senior high schools often fail to provide the compulsory practical periods required for science subjects (Ghana Education Service, 2019).

Research conducted by Ampiah (2008) revealed that students' exposure to laboratory training and practical work in schools is inadequate due to time constraints, overloaded curricula, and insufficient equipment. He further suggested that the West African Examinations Council should emphasize science process skills that do not rely heavily on extensive laboratory resources. Rather than being systematically structured, laboratory practical activities in many schools are frequently overlooked or replaced with theoretical instruction. This trend was also reported by Musah (2022), who found that physics practical activities are often not given the required priority due to competing instructional pressures and inadequate supervision.

Related studies further indicate that limited practical engagement in physics, particularly in optics-related topics, is a widespread issue in Ghanaian senior high schools. Teacher surveys reveal that practical activities are often conducted irregularly or restricted to periods close to external examinations (Ampiah & Adu-Gyamfi, 2020). Although the absence of structured laboratory time may adversely affect the acquisition of science process skills, available evidence suggests that students in such contexts often demonstrate measurable underperformance in physics practical outcomes. Chief Examiners' reports from the West African Senior School Certificate Examination consistently highlight candidates' weaknesses in accurate measurement, manipulation of apparatus, interpretation of experimental data, and communication of results, particularly in optics-related questions (West African Examinations Council [WAEC], 2021). These deficiencies reflect low acquisition of science process skills that are typically developed through regular and well-structured laboratory practical activities (Hofstein & Lunetta, 2004; Etkina et al., 2010).

Empirical studies conducted in Ghanaian senior high schools further demonstrate that limited exposure to laboratory practical activities is associated with poor performance in physics practical assessments and weak demonstration of essential process skills (Ampiah & Adu-Gyamfi, 2020). This evidence suggests that the lack of structured laboratory time has direct negative implications for students' learning outcomes.

Therefore, the specific problem addressed by this study is that many senior high schools in the Fanteakwa District of the Eastern Region fail to allocate and effectively utilize the mandatory laboratory time for physics practical activities, resulting in limited opportunities for students to improve their acquisition of essential science process skills. Consequently, this study seeks to enhance students' science process skills in selected topics in optics through frequent laboratory practical activities. Understanding the effect of such activities on students' skill acquisition is crucial, as the findings may guide teachers, school administrators, and policymakers in strengthening physics instruction and improving students' scientific competence.

1.3 Purpose of the Study

The purpose of this study was to examine the extent to which frequent laboratory practical activities can improve students' science process skills in selected topics in optics among Senior High School physics students in the Fanteakwa District of the Eastern Region of Ghana.

1.4 Objectives of the Study

The objectives of this study were to:

(i) determine the extent of science process skills of Form Two Senior High School science students in the Begoro Presbyterian Senior High before being exposed to frequent laboratory practical activities.

i. determine the extent of science process skills of Form Two Senior High School science students in the Begoro Presbyterian Senior High after being exposed to frequent laboratory practical activities.

ii. determine the correlation between the frequency of laboratory practical activities and the acquisition of science process skills among

iii. determine students' perception towards frequent laboratory practical activities on the acquisition of science process skills.

1.5 Research Questions

The study answered the following research questions.

(i) What are the extent of science process skills of Form Two Senior High School science students in the Begoro Presbyterian Senior High before being exposed to frequent laboratory practical activities?

(ii) What are the extent of science process skills of Form Two Senior High School science students in the Begoro Presbyterian Senior High after being exposed to frequent laboratory practical activities?

(iii)What is the correlation between the frequency of laboratory practical activities and the acquisition of science process skills in physics among students?

(iv)What are the students' perceptions toward frequent laboratory practical activities on the acquisition of science process skills?

1.6 Null Hypotheses (H_0)

The following null hypotheses was formulated for the study:

H_0: frequent laboratory practical activities has no significant effect on students' science process skills.

1.7 Significance of the Study

The students are expected to record improved performance in acquisition of science process skills in the selected topics in optics. Other physics teachers were are likely to adopt frequent laboratory practical activities to improve students' science processes.

1.8 Delimitation

Delimitation refers to the process of setting boundaries or limitations on a research study, typically by specifying the scope, focus, and parameters of investigation (Johnson, 2018). As the research was conducted in a school setting, Presbyterian Senior High School in Fanteakwa North, the students were the main participants in this study. This might have sensitized them to the intervention strategies. Knowing that they were participating in a study, the students may have participated in the laboratory practical activities differently from what they would have done under normal laboratory practical work. The study was also delimited to Form 2 physics students, the teaching syllabus for physics as prescribed by Ghana Education Service. Once more, the study took into account a few chosen optical physics topics.

This study was delimited to experimentation, observation, measurement, reading, and recording of data, data analysis, communication, and prediction as science process skills to be considered.

1.9 Limitations

Limitations are matters and occurrences that arise in a study that are out of the researchers' control (Simon, 2011). Simon claims that restrictions limit the scope of a study and occasionally have an impact on the findings and inferences that may be made. In this research, several factors could confound the study. These factors include students' prior knowledge, teaching methods, classroom environment, and student motivation (Kumar & Chandra, 2019).

Students' prior knowledge of some aspects of laboratory practical activities could influence their ability to engage in laboratory activities which may affect the outcomes of the study (NRC, 2012). Additionally, teaching methods, such as inquiry-based learning, could either enhance or hinder students' ability to acquire science process skills (Dori & Belcher, 2005). Moreover, the classroom environment, including the availability of resources and the quality of supervision can also affect students' learning outcomes (Keys & Bryan, 2001). Furthermore, student motivation plays a crucial role in their engagement, participation, and investment in laboratory activities, thereby influencing skills development (Anderman & Anderman, 2010). There may also be other relevant factors that could equally contribute to the acquisition of science process skills of the students but these were not examined due to time constraints.

1.10 Operational Definition of Terms

For clarity, the following important terms used in this study are defined:

Frequent Laboratory Practical Activities: In this study, this refers to the regular, planned, and repeated hands-on physics laboratory activities conducted for Form Two Senior High School science students in the Begoro Presbyterian Senior High School during the teaching of selected topics in optics, as opposed to occasional or exam-oriented practical work.

Science Process Skills: These refer to the basic and integrated scientific skills that students use in learning science, specifically observing, measuring, experimenting, inferring, and communicating, as measured by the students' performance on the science process skills test used in this study.

Improvement: Improvement refers to a measurable increase in students' science process skills scores after being exposed to frequent laboratory practical activities in selected optics topics.

Selected Topics in Optics: This refers to the specific optics concepts chosen from the Senior High School Physics syllabus for this study, such as reflection, refraction, and image formation, which were taught using frequent laboratory practical activities.

Students: Students refer specifically to Form Two Senior High School science students in the Fanteakwa District of the Eastern Region of Ghana who participated in the study.

Acquisition of Science Process Skills: This refers to the extent to which students develop and demonstrate science process skills as a result of engaging in frequent laboratory practical activities, as determined by their test and assessment scores.

Perception: Perception refers to students' opinions, beliefs, and attitudes toward the use of frequent laboratory practical activities in learning optics, as measured using a questionnaire.

Physics Practical Activities: This refers to structured hands-on experiments and laboratory exercises in optics that require students to manipulate apparatus, take measurements, record observations, and draw conclusions.

1.11 Organization of the Study

The study is organized into five chapters. Chapter One introduces the study by presenting the background, statement of the problem, objectives, and research questions. Chapter Two reviews relevant literature related to the topic. Chapter Three outlines the research methodology used to conduct the study. In Chapter Four, the results are presented, analysed, and discussed, and the research questions are addressed. Finally, Chapter Five provides a summary of the main findings, presents the conclusions drawn from the study, and offers recommendations based on the results.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter presents a review of literature related to the study. For clarity and effective presentation, the review is organised under several subheadings. The first subheading discusses the theoretical framework that forms the basis of the study. This is followed by sections on the historical development of practical activities in science, the concept of practical work in science education, and the nature of practical activities. The chapter further examines the advantages and disadvantages associated with the organisation of laboratory practical activities, as well as the teaching methodologies used in science education. It concludes with a review of empirical studies on laboratory practical activities and their influence on the acquisition of science process skills.

2.1 History of Practical Activities in Science Education

According to Serwaa-Ampaafo (2017), the value and purpose of practical activities in science education have long been subjects of discussion and debate. Despite these debates, practical activities have continued to remain an essential component of science education in schools. One distinguishing feature that sets science apart from many other subjects at the secondary school level is the inclusion of practical activities as part of formal instruction. Bennett, as cited in Serwaa-Ampaafo (2017), noted that although practical activities are recognised as an important part of the science curriculum in Ghana, the quantity and time allocated to them are relatively limited compared to what is observed in some other countries. Abrahams and Millar (2008) also indicate that many physics teachers regard practical activities as a fundamental aspect of teaching and learning science.

In contemporary science education, it is difficult to discuss the subject without considering the role of practical activities. Abrahams and Millar further emphasize that many teachers perceive practical work as central to the attractiveness and effectiveness of science education (p. 194). This idea is often supported by the well-known saying, “I hear and I forget, I see and I remember, I do and I understand,” originally attributed to Confucius (as cited in Krivickas & Krivickas, 2007), which highlights the importance of learning through active participation.

During the late nineteenth and early twentieth centuries, the rise of progressive educational philosophies strengthened the role of laboratory practical activities in science education. Influenced by the pragmatic educational ideas of John Dewey, educators began to shift from traditional teacher-centred approaches toward more active and experience-based learning methods (Dewey, as cited in Dobber et al., 2017). Laboratory experiments were therefore introduced as an effective means of engaging students in the scientific process, enabling them to investigate, discover, and build knowledge through direct experience.

One of the key proponents of this hands-on approach was Jean Piaget, whose theories of cognitive development emphasized the importance of sensory experiences and physical interactions in learning (Piaget as cited in Olagbaju, 2023). Piaget argued that children actively construct their understanding of the world through exploration and experimentation, a notion that resonated with the principles of laboratory-based science education. Similarly, Lev Vygotsky's sociocultural theory highlighted the purpose of social interaction and collaborative learning in cognitive development. Laboratory practical activities provided opportunities for students to engage with peers, discuss findings, and collectively construct meaning, thereby enhancing their understanding of scientific concepts and processes.

As science education continued to evolve, particularly in the realm of physics, educators like Arons (as cited in Dreyfus, et al., 2015) emphasized the need for laboratory activities that went beyond mere demonstration of principles to actively engage students in inquiry-based exploration). Arons advocated for experiments that encouraged students to formulate hypotheses, design procedures, collect data, and draw conclusions, mirroring the practices of professional scientists.

In the late 20th and early 21st centuries, research began to shed light on the efficacy of laboratory practical activities in achieving educational goals. Studies by scholars such as Karplus and Atkin demonstrated that hands-on experimentation not only facilitated conceptual understanding but also promoted the development of scientific reasoning and problem-solving skills (Karplus & Their as cited in Smetana & Bell, 2012). These findings underscored the importance of integrating laboratory experiences into science curricula as a means of fostering not only content knowledge but also scientific literacy and inquiry skills.

In recent years, advancements in technology have further enhanced the scope and impact of laboratory practical activities in science education. As indicated in Corter, et al., (2011) virtual simulations, remote labs, and computer-based data analysis tools have expanded access to hands-on learning experiences, allowing students to engage in authentic scientific inquiry regardless of physical constraints. Additionally, research in fields such as cognitive science and educational psychology continues to inform best practices for designing and implementing effective laboratory experiences that maximize student learning and engagement (Hofstein & Lunetta, 2004).

The history of laboratory practical activities in science education is characterised by a progressive evolution towards more student-centred, inquiry-based approaches. From the early contributions of pioneering educational theorists to the present integration of technology-enhanced learning tools, laboratory experiences have continued to be a fundamental component of science education, promoting the development of scientific knowledge, skills, and attitudes.

However, Driver (as cited in Serwaa-Ampaafo, 2017) pointed out that involving students in practical activities does not automatically lead to improvement in their understanding of science. In certain situations, practical activities may not produce the expected outcomes or phenomena anticipated by the teacher. When this occurs, students may become confused or lose interest, as they may begin to wonder whether the scientific theory is incorrect or whether the results obtained from the practical activity contradict the predictions of the theory.

Nevertheless, despite the continuing debates about the effectiveness of practical activities, they remain an integral part of science teaching. Wickman (2002) argued that some teachers use practical activities as a means of managing students' behaviour in the classroom. Consequently, practical activities are not always used in ways that effectively support or improve students' learning processes (Abrahams & Millar, 2008).

2.2 Theoretical Framework Related to the Important Aspect of the Study

The theoretical framework guiding this study is mainly based on constructivist learning theory, while also drawing support from social constructivist theory and the cognitive apprenticeship model. These perspectives help explain how frequent laboratory practical activities can influence students' development of science process skills in physics optics.

Laboratory practical activities have long been acknowledged as an essential aspect of effective science teaching, particularly in promoting conceptual understanding and strengthening science process skills such as observation, measurement, experimentation, data analysis, and communication (Hofstein & Lunetta, 2004). In physics, especially in the area of optics, meaningful learning occurs when students participate in both hands-on and minds-on activities. Through such engagement, learners interact directly with physical phenomena like light, lenses, mirrors, and refraction equipment.

Constructivist learning theory explains that learners build their own understanding through active interaction with their surroundings rather than simply receiving information passively (Driver & Bell, as cited in Eshach & Fried, 2005). This perspective closely relates to the purpose of the current study, which aims to assess students' science process skills before and after they participate in frequent laboratory practical activities, and to investigate the relationship between the frequency of practical activies and the acquisition of these skills.

According to Piaget's constructivist theory, learning occurs through the processes of assimilation and accommodation, which lead to cognitive development (Piaget, as cited in Schunk, 2012). Assimilation occurs when students apply prior knowledge to interpret new experiences, such as using existing ideas about light to explain observations made during optics experiments (Gordon, 2015). Accommodation, on the other hand, takes place when students revise their existing mental structures in response to experimental outcomes that contradict prior understanding, such as unexpected patterns of refraction or image formation (Pratiwi et al., 2019). These processes are central to the development of science process skills, as students learn to observe carefully, analyse data, test hypotheses, and draw evidence-based conclusions.

Frequent laboratory practical activities provide repeated opportunities for students to engage in assimilation and accommodation, thereby strengthening their science process skills over time. This theoretical position directly supports the study's objectives of determining changes in the extent of science process skills before and after sustained exposure to practical activities, as well as examining the relationship between activity frequency and skill acquisition.

In addition, social constructivist theory, rooted in the work of Vygotsky, emphasises the role of social interaction and guided learning in cognitive development (Vygotsky as cited in Palincsar, 2012). Learning is viewed as a socially mediated process in which students construct understanding through collaboration, dialogue, and interaction with more knowledgeable others. Within the physics laboratory, students work in groups, discuss observations, share interpretations, and receive guidance from teachers. Such interactions promote the development of higher-order science process skills, including communication, reasoning, and critical thinking (National Research Council, 2000).

This perspective is particularly relevant to the objective that seeks to determine students' perceptions of frequent laboratory practical activities, as students' attitudes towards practical activities are shaped by collaborative experiences, teacher scaffolding, and active engagement during laboratory activities (La Braca & Kalman, 2021).

The cognitive apprenticeship model further complements this framework by emphasising learning through guided participation in authentic tasks, where novices learn from experts through modelling, coaching, scaffolding, articulation, reflection, and exploration (Collins, Brown, & Newman, as cited in Herrington et al., 2014). In the physics laboratory, frequent practical activities allow students to observe expert demonstrations, practise scientific procedures, receive feedback, and reflect on their learning. These processes support the development of science process skills such as observation, measurement, experimentation, data analysis, and problem-solving (Collins et al., 2016).

Exploration, a key component of the cognitive apprenticeship model, is particularly facilitated through laboratory practical activities, as students are encouraged to investigate physical phenomena first-hand, test predictions, and refine their understanding through inquiry (Kuhn et al., 2017). Such experiences promote critical thinking, hypothesis testing, and scientific reasoning, which are essential components of science process skills (Agustini et al., 2024).

Taken together, constructivist learning theory, social constructivist theory, and the cognitive apprenticeship model provide a coherent and complementary theoretical foundation for this study. They explain how frequent, well-structured laboratory practical activities in physics optics can enhance students’ science process skills, influence learning outcomes, and shape students’ perceptions of practical-based physics instruction. These theories therefore align directly with the objectives of the study and justify the investigation into the effect of frequent laboratory practical activities on the acquisition of science process skills among senior high school physics students.

2.3 The Conceptual Framework of the Study

The conceptual framework for this study explains how frequent laboratory practical activities influence students’ attitudes, perceptions, and science process skills in selected topics in optics through a set of mediating learning processes. In this study, the independent variable is the frequency of laboratory practical activities. Practical activities are recognized as a central component of effective science teaching because they allow students to actively engage with scientific concepts, materials, and procedures rather than learning them only theoretically (Millar, 2004). The framework proposes that the effect of frequent laboratory practical activities on students’ learning outcomes occurs through three mediating processes**:** cognitive, behavioural, and social mediation.

Cognitive mediation involves hands-on application and sensory reinforcement. When students manipulate apparatus, observe phenomena, and test ideas, they build stronger mental representations of scientific concepts. Constructivist learning theory emphasizes that knowledge is actively constructed through interaction with the environment, and practical activities provide rich experiences that support conceptual understanding (Kolb, 1984). Such experiences help students link abstract optics concepts to real-world observations, strengthening both understanding and retention (Hofstein & Lunetta, 2004).

Behavioural mediation operates through repetition of techniques and error-correction cycles. Frequent laboratory engagement allows students to repeatedly practice measurement, observation, and experimental procedures, leading to skill refinement and improved accuracy. Behavioural learning theory suggests that repeated practice and feedback reinforce correct procedures and gradually eliminate errors (Skinner as cited in Schlinger, 2021). This continuous practice is essential for mastering science process skills such as measuring, experimenting, and observing (Etkina et al., 2010).

Social mediation involves peer collaboration and teacher scaffolding. During practical activities, students work in groups, discuss observations, and receive guidance from the teacher. Social constructivist theory emphasizes that learning occurs through social interaction and guided support from more knowledgeable others (Vygotsky as cited in Mishra, 2023). Teacher scaffolding and peer discussion help students clarify ideas, correct misconceptions, and develop scientific reasoning and communication skills (Hofstein & Kind, 2012). Through these mediating processes, frequent laboratory practical activities are expected to produce two main outputs. The first is students' attitudes and perceptions toward physics practical activities. Research indicates that regular involvement in hands-on activities increases students' interest, motivation, and positive attitudes toward science (Osborne et al., 2003; Hofstein & Mamlok-Naaman, 2007). The second output is the acquisition of science process skills, specifically experimenting, measuring, observing, communicating, and inferring. These skills are fundamental to scientific inquiry and are best developed through sustained and well-structured laboratory experiences rather than through theoretical instruction alone (Etkina et al., 2010; Hofstein & Lunetta, 2004).

Practical activities in this study include both student-performed laboratory exercises and instructor demonstrations (Abrahams, 2011). These activities involve students working with actual materials and apparatus, either independently or under teacher guidance, to observe, verify, and understand phenomena. Experiments, laboratory work, and practical activities are interrelated: student experiments are a subset of laboratory work, which is a subset of practical activities embedded in the physics curriculum (Reid & Shah, 2007). Physics is inherently inquiry-based and hands-on, and laboratory activities enhance both practical skills and conceptual understanding. Despite their importance, many laboratory exercises in schools are primarily prescriptive, offering limited opportunities for inquiry-based learning (Pyatt & Sims, 2007). Student-centred inquiry in the laboratory allows learners to meaningfully engage with tools, materials, and phenomena, expanding their understanding of scientific concepts (Raman et al., 2022). According to the American Association of Physics Teachers, laboratory objectives include experimentation, analytical and experimental skills, conceptual learning, understanding foundational physics knowledge, and collaborative learning (Holmes & Wieman, 2018). A three-stage learning cycle is considered essential for effective science learning. The first stage, exploration, allows students to relate their prior experiences to new phenomena. The second stage, concept introduction, involves the teacher guiding students to develop models that explain their observations. The third stage, concept application, enables students to solve problems and carry out investigations using the knowledge they have acquired (Hofstein & Lunetta, as cited in Zhang, 2024). For physics teaching to be effective, sufficient time must be allocated to each of these stages in order to support the development of students' science process skills (Hanif et al., 2008). Based on these considerations, the researcher posits that frequent laboratory exercises will significantly improve students' conceptual understanding and the acquisition of science process skills in physics.

Figure 1 presents the conceptual framework that guides this study.

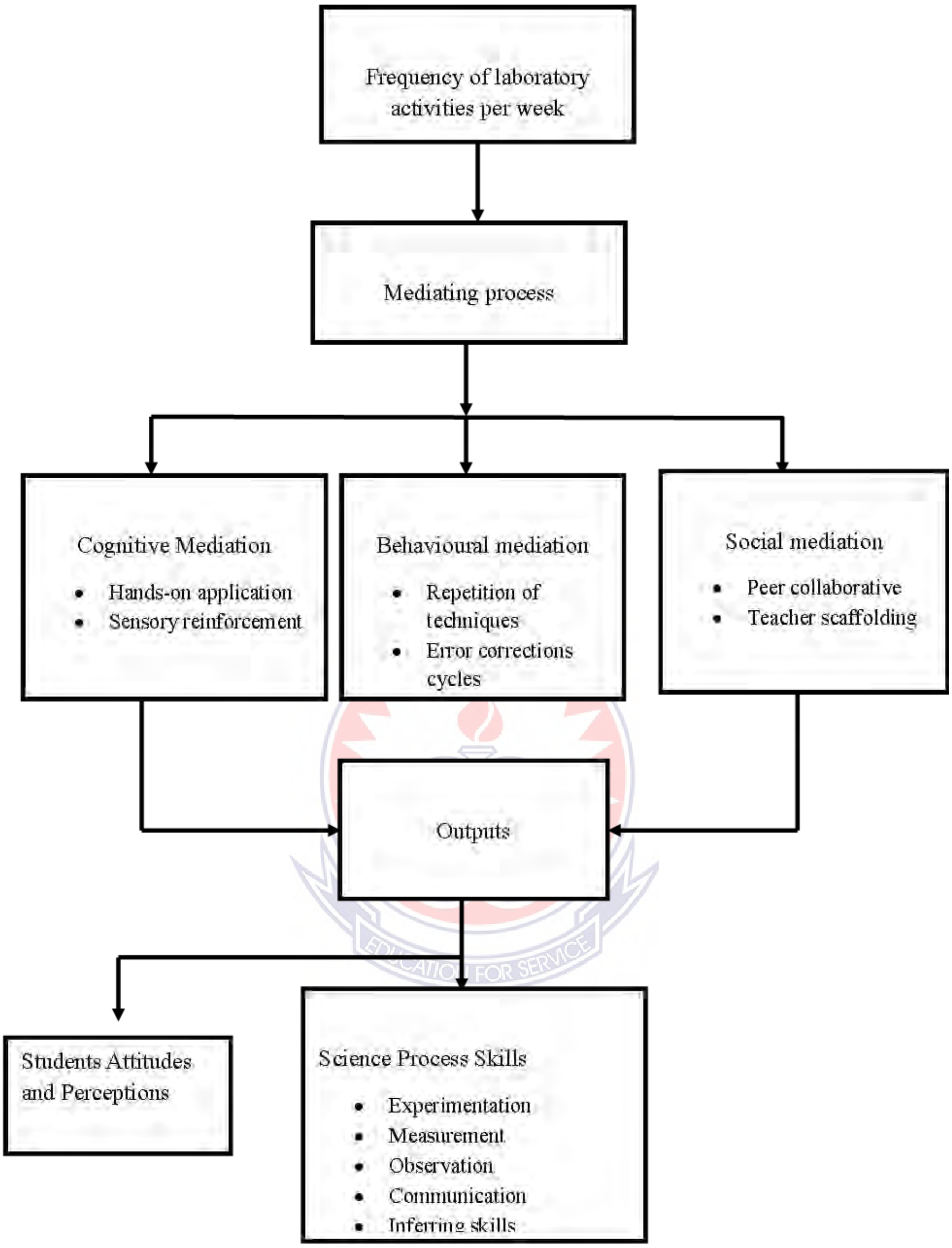


Figure 1: *Diagram illustrating the Conceptual framework of the study (Developed by Desmond Appiah, 2026).*

2.4 The Concepts of Practical Activity in Science Education

According to Abrahams (2011), the definition of practical activities in this study covers both laboratory exercises carried out by students and demonstrations conducted by the instructor. A practical activity refers to any instructional activity in which students observe or interact with real materials and objects during the learning process. This understanding is consistent with the interpretation of practical activities within the Ghanaian educational system, where students either manipulate equipment and materials themselves or observe teachers handling them during instruction.

In this study, the researcher also uses related concepts such as practical activities and laboratory activities by adapting the definitions proposed by Babalola (2017). Through laboratory activities, students participate in learning experiences that enable them to interact with materials in order to observe and verify scientific phenomena within the laboratory setting. A practical activity can also be described as a teaching approach that enables learners to perform and practise the various tasks involved in conducting practical investigations related to their field of study.

Experiments, laboratory activity, and practical activities are closely connected. Reid and Shah (2007) explain that student experiments form a subset of laboratory work, which itself is a subset of practical activities, and these are all components of the physics curriculum. Physics, by its nature, is an inquiry-based discipline that involves both hands-on engagement (doing) and minds-on engagement (thinking). For this reason, practical activities are generally considered essential in the study of physics. Laboratory activities support the development of practical skills and improve students' ability to understand theoretical concepts. For over a century, laboratory-based practical activities have held a unique and significant position in physics education (Hofstein & Mamlok-Naaman, 2007).

However, these authors point out that many students' laboratory practical activities mainly involve manipulating equipment (doing) rather than engaging deeply with ideas (thinking). Education researchers view the school science laboratory as a valuable resource that can increase students' interest in science and promote a deeper understanding of scientific concepts and procedures. Through school laboratory practical activities, students can also develop an understanding of the nature of science, which is important for comprehending scientific knowledge (Lunetta, Hofstein & Clough as cited in Abrahams, Reiss & Sharpe, 2011).

Despite the fact that laboratory exercises are acknowledged as being crucial to the teaching and learning of physics, many physics instructors actually lack the skills necessary to plan and execute successful laboratory instruction (Kamarudin, 2018).

A study has shown that most practical tasks in science laboratory manuals are prescriptive, providing little or no opportunity for open-ended or inquiry-based learning and that practical work can be unproductive and learning of science goes on with students in practical classes as indicated in Pyatt and Sims (2007). Given the resurgence of student-centred inquiry as a contemporary approach to science education, the laboratory is particularly crucial. According to Ma and Nickerson (cited in Raman et al., 2022), students can only engage in meaningful learning in the lab if they are provided with ample opportunity to work with actual tools and materials in a setting that allows them to expand their understanding of phenomena and associated scientific ideas.

According to the American Association of Physics Teachers (as cited in Holmes & Wieman, 2018), the basic physics laboratory has five main objectives. The first objective is the art of experimentation. To achieve this, introductory laboratory work should provide students with meaningful exposure to experimental procedures, including opportunities to design and carry out investigations.

The second objective focuses on analytical and experimental skills. In this regard, laboratory practical activities should help students develop a variety of essential skills and tools related to experimental physics as well as techniques for processing and analysing data. The third objective is conceptual learning**,** where the laboratory is expected to support students in understanding key physics concepts.

The fourth objective is understanding the basis of physics knowledge. This goal emphasizes that laboratory practical activities should enable students to appreciate the importance of direct observation in physics and learn to distinguish between conclusions drawn from theoretical ideas and those obtained from experimental evidence. The final objective is the development of collaborative learning skills. Laboratory practical activities should therefore provide opportunities for students to work together, as teamwork is an important skill for success in many lifelong pursuits. Drawing on Piaget's learning theory, Hofstein and Lunetta (as cited in Zhang, 2024) proposed a three-stage learning cycle that supports effective science learning. The first stage is exploration, where students rely on their prior experiences and are encouraged to connect their existing knowledge with the new concepts being studied. The second stage is concept introduction, during which the teacher guides students toward developing a model or explanation that accounts for the observations made during the exploration stage. The final stage is concept application, where students engage in problem-solving and laboratory practical activities, applying the knowledge gained in the previous stage to new situations.

As indicated in the physics teaching curriculum, science teachers are expected to allocate adequate time and attention to each of these three stages in order to facilitate the development of students' science process skills. However, researchers and educational authorities in different countries do not always agree on the specific objectives of physics laboratories or on the most appropriate ways to assess them (Hanif et al., 2008).

2.4 Some Advantages of Practical Activities in Teaching and Learning of Physics

For a considerable amount of time, laboratory exercises have been an integral part of the physics curriculum, serving as a means of understanding the natural world (Hofstein & Lunetta, 2004). They further stated that physics teachers have long argued that getting kids involved in the science laboratory has numerous advantages. The extensive body of written work demonstrates how the laboratory offers a special approach to teaching, learning, and evaluation Lerner (2009).

The physics teaching syllabus outlines the main purpose of studying physics at the senior high school level. According to the syllabus, physics as a discipline is concerned with the nature of matter and energy, their interactions, and their measurement. The study of physics has a significant impact on the global community (Schweber, as cited in Jusup et al., 2022). The knowledge, skills, and attitudes developed through the study of physics are widely applied in various scientific and technological advancements (Soh, Arsad, & Osman, 2010). Furthermore, the principles and applications of physics extend to many aspects of everyday life, such as walking, lifting objects, seeing, and taking photographs (Bloomfield, 2015). The aims outlined in the Senior High School Physics syllabus (MOE, 2010) are to:

a) Provide, through well-designed studies of experimental and practical physics, a worthwhile hands-on educational experience to become well-informed and productive citizens.

b) Enable the Ghanaian society to function effectively in a scientific and technological era, where many utilities require basic physics knowledge, skills, and appropriate attitudes for operations.

c) Recognise the usefulness, utilization, and limitations of the scientific methods in all spheres of life.

d) Raise the awareness of inter-relationships between physics and industry, Information, and Communication Technology (ICT), Agriculture, Health, and other daily experiences.

e) Develop in students, skills and attitudes that will enable them to practice science most efficiently and cost-effectively.

f) Develop in students the desirable attitudes and values such as precision, honesty, objectivity, accuracy, perseverance, flexibility, curiosity, and creativity.

g) Stimulate and sustain students' interest in physics as a useful tool for the transformation of society.

In order to achieve these aims, the syllabus is structured in a way that the student will have to go through both practical activities and theory. The practical activities play a major role in acquiring skills, attitudes, and values needed to fit well in society. Some studies have shown that laboratory practical activities offer myriad advantages for students' learning and the cultivation of science process skills, contributing to a comprehensive understanding of the subject. For example, the hands-on nature of these experiments allows students to directly interact with physical phenomena, closing the distance between abstract theories and real-world applications (Wong & Chiang, 2019). Also by manipulating equipment, observing, and conducting experiments, students gain a deeper appreciation for the underlying principles of physics. Such experiential learning not only enhances conceptual understanding but also promotes the retention and transfer of knowledge across different contexts (Prince, 2004). Moreover, practical activities cater for diverse learning styles, accommodating visual, auditory, and kinaesthetic learners alike, thereby ensuring equitable access to education (McLeod, 2018). In addition to fostering conceptual understanding, physics practical activities facilitate the development of critical thinking and problem-solving skills (Ward &

Jenkins, 2018). As students engage in data gathering, analysis, and interpretation, they are challenged to think analytically and logically. Furthermore, encountering unexpected results or experimental errors prompts students to troubleshoot and refine their methodologies, honing their capacity to think creatively and adapt to changing circumstances (NRC, 2012). This iterative process of inquiry not only enhances students' understanding of physics concepts but also instils a growth mind-set, encouraging them to embrace challenges as opportunities for learning and growth (Dweck, 2006).

Moreover, practical activities empower students to take ownership of their learning through inquiry-based approaches. By posing questions, designing experiments, and formulating hypotheses, students actively engage in the scientific process, fostering curiosity and intrinsic motivation (Bell, Smetana & Binns, 2005). Furthermore, collaborative learning experiences during practical activities encourage peer interaction and communication, promoting the exchange of ideas and the development of interpersonal skills (Johnson & Johnson, 2009). Additionally, engaging in authentic scientific inquiry allows students to appreciate the iterative nature of scientific discovery, emphasizing the importance of evidence-based reasoning and critical evaluation (Lederman & Lederman, 2014). Physics practical activities serve as catalysts for the development of science process skills, providing students with opportunities for hands-on exploration, critical thinking, and inquiry-based learning (Bogador, et al., 2024). By encouraging a more profound comprehension of physics concepts and promoting essential skills for scientific inquiry, practical activities play a pivotal role in preparing students for success in both academic and real-world settings (Kotsis, 2024). Although there is wide variation in the quality of practical activities, there is compelling evidence worldwide that, when properly designed and executed, science education laboratory and simulation experiences place students' learning in different levels of inquiry and necessitate mental and physical engagement in ways that other science education experiences cannot (Lunetta, Hofstein & Clough, 2007). Practical activity, when well organized, can increase students’ sense of ownership of their learning and can increase their enthusiasm. Toplis (2012) noted that by enabling students to "visualise" the rules and theories of science, practical exercises can enhance their comprehension of science and foster their conceptual development, helping them to make sense of the numerous goals. As a result, it can support, validate, or exemplify theoretical work; Arguments that are affective: It has been stated that engaging in practical activities inspires motivation and excitement, generating interest and passion. Practical activities help students retain and reinforce the knowledge they acquire. Furthermore, arguments that emphasize skill development suggest that hands-on practical activities promote higher-order and transferable abilities such as observation, measurement, prediction, and inference, in addition to developing manipulative or physical skills (Abrahams, 2009). These transferable abilities are considered useful not only for individuals who pursue scientific careers but also for their broader practical and vocational applications (Nägele & Stalder, 2017). Some researchers have also indicated that practical activities can strengthen students’ sense of ownership over their learning and enhance their motivation, as reported by Reiss and Abrahams (2015).

Millar (2010) emphasizes the importance of hands-on science experiences in the classroom. Specifically, such practical activities enable students to experience the challenges involved in measurement and to understand the unavoidable uncertainty or errors associated with it. They also serve as an effective means of teaching experimental design. The laboratory environment can therefore provide a meaningful setting for learning, where students' existing ideas about natural phenomena can be examined, challenged, and reconstructed (Lunetta et al., 2007).

These researchers further argue that the school science laboratory is a distinctive resource capable of increasing students' interest in science while also improving their understanding of scientific concepts, procedures, and the tools and skills used in scientific investigations. They also concluded that experiences gained through laboratory practical activities can expose students to ideas about the nature of science, which are essential for understanding scientific knowledge. Ndoro (as cited in Shivolo & Mokiwa, 2024) also maintains that laboratory practical activities are fundamental to the teaching and learning of physics because they provide students with practical experiences that help them develop science process skills.

Science process skills include a variety of abilities such as observation, measurement, data collection, analysis, inference, and communication (Gizaw & Sota, 2023). This review therefore seeks to examine how frequent laboratory practical activities contribute to the improvement of science process skills among students studying physics. Evidence from research suggests that frequent laboratory practical activities have a significant positive influence on the development of students' science process skills in physics education (Hodosyova et al., 2015).

Students develop their observation, measurement, data collecting, analysis, inference, and communication abilities through practical experimentation, which helps them comprehend basic physics topics more deeply (Schwichow et al., 2016). Educators should continue to prioritize the integration of practical laboratory activities into the physics curriculum to foster the holistic development of students' scientific abilities (Hofstein & Lunetta, 2004). Frequent engagement in laboratory practical activities allows students to improve their observation skills by directly interacting with physical phenomena. According to Tobin (as cited in Shana & Abulibdeh, 2020), students who regularly participate in laboratory experiments demonstrate greater attentiveness to detail and an increased ability to identify patterns and trends within experimental data. Practical laboratory activities provide students with opportunities to refine their measurement techniques through repeated practice. As noted by Johnson (2019), the hands-on nature of laboratory experiments allows students to develop proficiency in using scientific instruments and recording accurate measurements, thereby enhancing their quantitative skills. They learn to draw logical conclusions based on evidence gathered during laboratory activities (Adams & Lee, 2015). Laboratory practical activities stimulate students' ability to make inferences and engage in critical thinking by providing opportunities for hypothesis testing and problem-solving. According to Petritis, Kelley, and Talanquer (2021), students who actively participate in laboratory investigations develop stronger deductive reasoning skills and demonstrate a heightened capacity to construct scientific explanations based on empirical evidence. Students can use their theoretical knowledge to predict experiment results by participating in practical laboratory activities (Miller, 2018). Through trial and error, they refine their predictive abilities and gain a detail understanding of scientific concepts (Chen & Wang, 2020). Students formulate hypotheses to explain observed phenomena and design experiments to test these hypotheses (Smith, Lee & Johnson, 2019). By conducting controlled experiments and analysing results, they learn to evaluate the validity of their hypotheses (Clark, 2016). Along with learning how to read graphs and tables, students also learn how to record and analyse data (Wilson, 2018). Through laboratory practical activities, students learn various data analysis techniques, such as statistical analysis and graphical representation (Gomez, 2017). By analysing data to reach insightful conclusions, they strengthen their critical thinking abilities (Martinez, 2019). The implementation of frequent laboratory practical activities encourages students to collect and analyse data, promoting understanding of physics concepts. Research by Brown and Jones (2020) highlighted that students who engage in regular laboratory experiments exhibit improved data interpretation skills and a greater capacity to draw meaningful conclusions from experimental results. Students communicate their findings through written reports, oral presentations, and discussions (Johnson & Garcia, 2020). Laboratory activities foster effective communication skills as students articulate their procedures, results, and interpretations to peers and instructors (Adams, 2018). Frequent laboratory practical activities foster the development of effective communication skills, as students are required to articulate their findings and conclusions through written reports or oral presentations. As indicated by Schultz (2010) students who regularly engage in laboratory experiments demonstrate improved clarity and coherence in their scientific communication, thereby enhancing their ability to convey complex ideas to others. Frequent laboratory practical exercises assist students improve these skills and increase their enthusiasm in pursuing higher-level physics and related courses.

2.6 Some Demerits of Laboratory Practical Activities

Though experiments may aid in postulating a problem, they sometimes prove not only to be superfluous but harmful in achieving those skills that they hope to help attain. Abrahams and Millar (2008) concurred and ascribed this detrimental effect to the learner's focus being diverted from the problem's fundamental theoretical aspects while simultaneously being fixated on "salient aspects" of the actual circumstance. The question of whether the laboratory can be most effectively utilized in the training of future scientists remains unresolved and, at times, highly debated. A degree in the natural sciences (physics, chemistry, biology) that lacks a substantial component of laboratory work, typically measured by the amount of time spent in the laboratory is often regarded as a "second-rate" qualification. Yet, it sometimes appears that the primary skills developed through laboratory activities are the relatively low-status manipulative skills. Abrahams (2009) noted that considerable debate exists regarding the effectiveness of laboratories in fostering science process skills. Several areas of concern have been identified in this regard, including the following:

i. Practical activities in physics often require specialized equipment and materials, which can be costly to procure and maintain (Brown, 2017). This might limit the frequency or variety of experiments conducted, particularly in schools with limited budgets. For example, experiments involving optics may require lasers or precision lenses, while those in electromagnetism may necessitate strong magnets or sensitive measuring instruments. Again, the availability of resources for physics practical activities is crucial for understanding the impact of laboratory practical activities on the development of science process skills in students. According to Smith and Jones (2019), access to adequate laboratory equipment and materials significantly influences the effectiveness of practical sessions in physics education. Additionally, Brown, Smith, and Davis (2020) stress the need of providing a range of resources to accommodate different learning preferences and enable practical experimentation, both of which are critical for developing science process skills. In educational settings, the availability of resources for physics practical activities varies depending on factors such as budget constraints, institutional support, and curriculum requirements (Johnson, 2018). Schools with limited resources may struggle to provide the necessary equipment and materials for conducting experiments, thereby hindering students' opportunities to develop science process skills through hands-on learning experiences. In considering the availability of resources for physics practical activities, it is important to consider the specific types of equipment and materials required for conducting experiments in various topics within physics. For instance, experiments in mechanics often necessitate equipment such as inclined planes, pulleys, and friction blocks, while electricity and magnetism experiments may require components like circuits, batteries, and magnets. Access to specialized equipment, such as spectrometers or oscilloscopes, is also crucial for advanced topics like optics and electronics. Moreover, the availability of consumable materials like batteries, wires, resistors, and various chemicals for experiments in thermodynamics, optics, and materials science is essential. These materials not only enable students to perform experiments but also encourage exploration and innovation in their scientific inquiries. Furthermore, the quality and maintenance of available resources also play a crucial role in the effectiveness of physics practical activities. Research by Garcia and Patel (2017) suggests that outdated or poorly maintained equipment can impede students' ability to engage in meaningful experimentation and data analysis, thereby limiting their development of science process skills. The availability and quality of resources for physics practical activities are fundamental factors that influence the development of science process skills in students. Adequate provision of equipment, materials, and maintenance support is essential for facilitating meaningful hands-on learning experiences in physics education. Hernandez and Martinez (2022) conducted a study examining the correlation between resource availability and student engagement in physics practical activities. They found that schools with well-equipped laboratories reported higher levels of student interest and participation in hands-on experiments, leading to improved learning outcomes. Wang and Chen (2019) also explored the role of digital resources, such as interactive simulations and virtual laboratories, in supplementing traditional physics practical activities. Their research suggests that integrating digital tools into the curriculum can enhance accessibility and provide additional avenues for students to explore complex concepts, especially in schools with limited physical resources. Lee and Park (2020) investigated the impact of teacher training and professional development programs on optimizing resource utilisation in physics education. They observed that educators who received specialized training in experiment design and resource management were better equipped to maximize the effectiveness of practical activities, even with limited resources. Chang and Wu (2021) explored innovative approaches to resource sharing and collaboration among schools to overcome budget constraints and enhance resource availability. Their research emphasized the potential benefits of establishing networked learning communities where schools can pool resources and expertise to enrich practical learning experiences for students. Researchers such as Kumar and Sharma (2023) delve into the importance of institutional investment in laboratory infrastructure. They argue that adequate funding for the establishment and maintenance of physics laboratories is essential for ensuring the availability of resources. Moreover, infrastructure investment includes not only the procurement of equipment and materials but also the provision of suitable laboratory space and facilities conducive to hands-on experimentation. Nguyen and Tran (2020) also explore the potential benefits of forging partnerships between educational institutions and external stakeholders, such as industry partners and research organizations. Collaborative initiatives can enhance resource availability by providing access to specialized equipment, expertise, and funding opportunities. By leveraging external resources, schools can expand their capacity to offer diverse and enriching practical activities to students. Researchers like Rodriguez and Gonzalez (2019) also advocate for the integration of open educational resources (OER) into physics curricula. OER, including online simulations, virtual laboratories, and instructional videos, offer cost-effective solutions to supplement traditional laboratory resources. Their accessibility and flexibility make them particularly valuable for schools with limited budgets or those facing logistical challenges in procuring physical equipment. Chen and Li (2021) highlight the importance of empowering physics educators to creatively adapt and innovate with available resources. Professional development programs that focus on pedagogical strategies, experiment design, and resource utilization enable teachers to make the most of limited resources. Moreover, fostering a culture of collaboration and resource sharing among educators can further enhance the collective capacity to deliver high-quality practical activities. Finally, researchers such as Park and Kim (2018) explore the role of technological advancements in expanding resource availability. Emerging technologies, including 3D printing, sensor technologies, and data logging devices, offer new possibilities for hands-on experimentation in physics education. In addition to making experimental setups more affordable and accessible, these technologies give students access to state-of-the-art instruments and techniques. A multifaceted approach to enhancing resource availability for physics practical activities involves investment in infrastructure, fostering community partnerships, integrating open educational resources, empowering teachers, and embracing technological advancements. By addressing these various dimensions, educational institutions can create an environment conducive to meaningful hands-on learning experiences and the development of science process skills in students. It appears many senior high schools across Ghana grapple with the stark reality of inadequate laboratory facilities and limited access to essential resources, presenting significant hurdles to the effective implementation of practical activities (Adjei, 2020; Boateng & Tetteh, 2019). Students are deprived of vital experiential learning opportunities that are necessary for comprehending scientific ideas and honing practical skills due to the lack of operational laboratories (Asare & Afari, 2018). Without access to well-equipped laboratories, students are unable to conduct experiments, analyse data, and draw meaningful conclusions, thereby impeding their mastery of scientific principles. Furthermore, the scarcity of resources such as laboratory equipment, chemicals, and consumables exacerbates the challenges faced by educators and students alike (Boateng & Tetteh, 2019). In many instances, outdated or malfunctioning equipment further compromises the quality of practical activities, hindering effective teaching and learning experiences (Adjei, 2020). Teachers often resort to improvised solutions or theoretical demonstrations, limiting the depth of students' understanding and engagement with scientific concepts (Asare & Afari, 2018). Consequently, the deficiency in laboratory facilities and resources not only impedes students' academic progress but also diminishes their preparedness for higher education and the workforce. Inadequate exposure to practical activities undermines the development of critical thinking, problem-solving, and experimental skills essential for success in STEM fields and beyond (Boateng & Tetteh, 2019).

ii. Setting up and conducting physics experiments can be time-consuming, potentially reducing the time available for other instructional activities (Hofstein & Lunetta, 2004). Teachers may struggle to cover the required curriculum within limited timeframes. Additionally, factors such as equipment calibration, data collection, and troubleshooting can further extend the duration of practical sessions, leaving less time for theoretical discussions or student engagement.

iii. Physics experiments often involve hazardous materials or equipment, posing safety risks to students if not conducted properly (Hofstein & Lunetta, 2004). Ensuring student safety may require additional supervision and precautions, adding to the logistical challenges of practical activities. For instance, experiments involving electricity or chemicals must adhere to strict safety protocols to prevent accidents or injuries (Brown, 2017)

iv. Due to inadequate teaching and learning materials in many secondary schools, not all students may have equal access to laboratory facilities or resources outside of regular class time (Dewhurst & Alsop, 2013). This can exacerbate inequalities in learning opportunities based on factors such as socioeconomic status or geographic location. Students from rural areas or under-resourced schools may have limited access to laboratory equipment or trained instructors, potentially hindering their ability to participate fully in practical activities and engage with hands-on learning experiences.

v. The necessity to prepare students for tests and the demand for hands-on learning experiences may conflict when practical activities don't always match curriculum guidelines or standardized assessments (Brown, 2017). Teachers may feel pressured to prioritize topics that are heavily emphasized in exams, sacrificing the depth or authenticity of practical experiences. This mismatch between assessment requirements and pedagogical goals can limit the effectiveness of physics practical activities in promoting meaningful learning outcomes.

vi. Some physics experiments involve complex measurements or data analysis techniques that may be challenging for students to grasp, particularly without adequate guidance or prior knowledge (Hofstein & Lunetta, 2004). Concepts such as uncertainty, error analysis, and statistical inference may be difficult to understand without hands-on experience and contextualization within experimental settings. As a result, students may struggle to interpret experimental results or draw meaningful conclusions from their observations.

vii. Dissatisfaction with the effectiveness of traditional laboratory activities, as they often fail to promote a deep understanding of scientific concepts or the practical application of scientific principles to problem-solving. Some comparative studies of conventional laboratory classes and other forms of teaching indicate shortcomings in the effectiveness of laboratory work. Although laboratory activity is thought to be more effective than other methods for acquiring observational and manipulative skills, others have argued that it is generally less effective for teaching factual knowledge, concepts, scientific inquiry, or problem-solving skills (Ampiah, 2004). Researchers such as Hart, et al., (2000) think that science laboratory activity is nothing more than learning "bench techniques". According to them almost half a century ago, summaries of research on the value of laboratory work experience for learning science did not favour the laboratory over lecture demonstration. It is not at all uncommon to find a student who shows absolutely no understanding of the processes and techniques that he or she applied even a day earlier in the laboratory. It is quite easy to perform practical work that does not involve any thinking at all cited in Wellington (2005). The abundance of information necessary to assimilate inside the laboratory along with the burden of reporting outside of the laboratory tends to result in laboratory journals evidenced by minimal thinking. Students rarely have the chance to spend time watching an expert experiment. There is thus a painful absence of a model that might set tangible standards as well as a clear concept of how a well-done experiment progresses. Finally, practicals are often seen as isolated exercises, bearing little or no relationship with earlier or future work (Thomas (as cited in Psillos & Niedderer, 2002)

2.7 Students' Attitudes and Perceptions toward Frequent Laboratory Practical Activity

Since the early introduction of activity-oriented science curricula, laboratory activities have occupied a central role at all levels of school science (Al-Naqbi & Tairab, as cited in Cossa & Uamusse, 2015). With the development of curricula in countries such as the United States, the United Kingdom, and beyond, science teaching has increasingly emphasized practical activities. These researchers identified two main reasons for this trend.

First, science is viewed as more than just a body of knowledge to be memorized. They argue that science belongs in the school laboratory just as naturally as cooking belongs in a kitchen or gardening in a garden. Consequently, the development of science process skills is equally important, and science education should prioritize fostering practical abilities through the use of diverse process skills during classroom experiments.

Second, according to Al-Naqbi and Tairab, the constructivist perspective of learning emphasizes active participation by the learner. Students are seen as individuals who actively construct their knowledge by engaging in meaningful learning activities. Therefore, practical activities in schools are expected to give students opportunities to build scientific knowledge through personal involvement in designing experiments, manipulating data, observing results, and making inferences and generalizations.

In Ghanaian schools, laboratory exercises play a crucial role in developing students' critical thinking, reasoning, problem-solving abilities, and science process skills. Learners' attitudes are also essential for encouraging engagement in these activities. Koballa and Glynn (2013) noted that the conceptual structure of scientific attitudes consists of both a scientific dimension and an affective dimension. The scientific dimension includes: (1) adherence to particular beliefs or worldviews, such as loyalty to truth or the belief that nature is understandable; (2) attitudes related to evaluating ideas and information; and (3) general dispositions toward ideas and information, including curiosity, open-mindedness, and creativity. The affective dimension, in contrast, relates more to an individual's willingness or inclination to use scientific procedures than to their actual ability to do so. Many national and local science curriculum guidelines and standards frequently include these attitudes among their learning objectives and expected outcomes. The main reasons are:

1. The adoption of scientific attitudes enables students to gain a deeper understanding of the scientific process because, to some extent, they assume the role of a scientist, with their behaviour guided by these attitudes (Barmby, Kind & Jones, 2008).
2. Scientific attitudes are valuable not only for professional scientists but also for all students in everyday life. When guided by these attitudes, students are more likely to approach problems systematically and evaluate information and ideas scientifically, which increases the chances of reaching effective solutions

(Barmby et al., 2008). According to Anwer, Iqbal, and Harrison (2012), attitudes reflect feelings of liking or disliking. Students who develop a better understanding of science and a positive disposition toward it are more likely to pursue further science courses and continue engaging with scientific knowledge.

Conversely, negative attitudes often lead to a lack of interest in the subject. When a student shows disinterest, it becomes challenging for them to successfully carry out practical activities. Prokop, Tuncer, and Chudá (2007) emphasized that science attitudes are learned and that teachers play a crucial role in shaping them. The teaching methods, behaviour, and interactions of teachers can strongly influence students’ attitudes toward learning science, which in turn can affect their academic achievement. They further noted that students’ attitudes toward science have a significant impact on their performance, and fostering positive attitudes toward practical work helps students develop inquiry skills essential in scientific learning. Ziedan and Jayosi (2015) discovered a correlation between attitude toward science subjects and science process skills. According to Abungu, Okere, and Wachanga (cited in Gizaw & Sota, 2023), the science process skills approach to instruction has a major impact on students' academic performance.

It is widely recognized that laboratory practical activities have become an integral historical and philosophical component of scientific learning and development, rather than merely a procedural methodology following a sequence of mental and practical steps. Factors such as high demands on laboratory space, instructors’ time, and experimental resources may also contribute to this situation. It is generally understood that if a child finds art more enjoyable than science, they may lack motivation to engage in science activities. However, when students are guided to find personal meaning in the subject, their motivation to learn science can increase. In other words, students who are motivated by laboratory activities tend to develop greater interest in science compared to other teaching methods Research has highlighted a disconnect between students' and teachers' perceptions regarding the purpose of laboratory activities (Hofstein & Lunetta, 2004). Students' initial understanding of experimental objectives often differs significantly from the goals articulated by teachers. Nevertheless, extended exposure to consistent experimental objectives in the classroom can improve alignment between student and teacher perceptions. Russell and Weaver (2008) observed that students who perceive the laboratory as disconnected from lecture sessions often feel that it does not support their learning of either lecture content or laboratory content. As a result, they fail to see the connection between what is taught in class and the practical activities in the laboratory Additionally, they discovered that students view the lab as a place that does not foster learning, which is important to consider when creating objectives for the lab and scientific courses in general. According to them, students perceive laboratory practical activities as just to restate what they were taught in class. Students perceived the laboratory as not a forum in which students are required to learn new concepts or ideas, but experiences of revisiting concepts that have been previously learned in the lecture portion of their course. It then appears that students see no difference between what they are taught in the class through lectures and the laboratory activities they go through. Students need to be made explicitly aware of the goals of the laboratory, both in terms of the laboratory and each experiment individually. This would be best accomplished before the commencement of any laboratory activities.

Students cannot be expected to accomplish particular objectives or fully comprehend the laboratory's purpose if they do not have a clear comprehension of their lecturers' objectives. According to Abrahams (2011), students viewed practical activities as a beneficial approach to bridging academic and real-world information and developing their manipulation abilities. Although many students reported enjoying practical activities, Cleaves (2005) also discovered that there was general disapproval of the idea that as students advanced through the educational system, less time was spent on practical activities in physics laboratory. It, therefore, seems that even though students wish to conduct more practical activities, possibly because they enjoy it over other methods of learning science, they do not feel that what is taught in their classes is the best that it could be. According to Abrahams, as cited in Osborne, Simon, and Collins (2003), the utilization of practical activities may lessen the negative perception of science among disillusioned and lower-ability students. More recently, Barmby et al. (2008) reported that students' attitudes toward practical activities decline slightly between Year 7 and Year 9. Overall, students tended to prefer practical activities over other methods of learning science. As one student noted, "I like science when you do practicals rather than when you're writing stuff" (Barmby et al., 2008, p. 1088). These findings are consistent with those of Abrahams (2009).

2.8 Scientific Process Skills to be acquired through Practical Activities

Science process skills are defined as the essential abilities that students need to engage effectively in scientific inquiry and problem-solving. Asio and Mondejar (2022) categorized these skills into fundamental and integrated processes. The fundamental skills, also referred to as basic processes, include observing, measuring, classifying, inferring, predicting, and communicating. These skills serve as the foundational abilities that support all scientific investigations.

In contrast, integrated process skills encompass more complex abilities such as controlling variables, making operational definitions, formulating hypotheses, developing models, interpreting data, and conducting experiments. These integrated skills are critical for enabling students to design and carry out comprehensive scientific investigations (Ssanti et al., as cited in Asio & Mondejar, 2022). According to Widyaningsih (2020), students' misconceptions and poor science learning outcomes are the result of the absence of experimental activities in the classroom. Hirca (2013) asserts that the development of integrated process skills will be built upon the foundation of fundamental process skills. Students will be influenced to approach environmental issues realistically by these science process skills (Dakabesi & Louise, 2022). A substantial amount of work needs to be done to develop excellent process skills and critical thinking. They are essential for students to develop a deep understanding of scientific concepts and to effectively engage in the scientific method. Other researchers, however, incorporate these two categories into a single integrated set of skills (Yang, Liu & Liu, 2019). Table 1 Presents the Science Process Skills along with a brief description.

Table 1: *List of Science Process Skills and their Description*

Science Process Skills	**Description**
Observing	Using the senses to gather information about an object or event
Inferring	Making an educated guess about an object or event based on previously gathered data or information
Measuring	Using standard and nonstandard measures or estimates to describe the dimensions of an object or event
Communicating	Using words or graphic symbols to describe an action, object, or event
Classifying	Grouping or ordering objects or events into categories based on properties or criteria
Predicting	Stating the outcome of a future event based on a pattern of evidence
Controlling variables	Identifying variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable
Defining operationally	Stating how to measure a variable in an experiment
Formulating Hypothesis	Stating the expected outcome of an experiment
Interpreting data	Organizing data and concluding it
Asking questions	Raising an appropriate question
Formulating models	Creating a mental or physical model of a process or event

Adapted from Yang and Liu (2016, p. 8)

According to Bell, Mulvey, and Maeng (2012), students' participation in the science process serves as a foundation for their comprehension of scientific ideas and concepts, making it a significant goal of science education. It is believed that acquiring science process skills is necessary for all citizens, not just those who plan to pursue careers in science (Harlen as cited in Gizaw & Sota, 2023). Individuals who possess science process skills are capable of tracking and understanding scientific advancements and participating in scientific decision decision-making processes (Turiman et al. 2012). Based on research findings, SPS development helps students perform better overall in science and other subject areas (Supriyatman & Sukarno, 2014). Additionally, it fosters a favorable attitude in students toward science instruction and scientific research (Zeidan & Jayosi, 2015). In this study, the researcher focused on experimenting, measuring, observing, communicating and inferring skills to be acquired through frequent laboratory practical activities.

2.8.1 Experimenting skill

As indicated in Idris, Talib, & Razali (2022), experimenting is a fundamental science process skill that involves designing and conducting investigations to test hypotheses and answer scientific questions. Experimenting skill may encompasses various sub-skills, including identifying variables, controlling conditions, collecting data, and analysing results (Padilla, 2012). Through experimentation, learners develop understanding of scientific concepts and improve their ability to engage in systematic inquiry (Kranz, Baur & Möller, 2023). An essential part of conducting experiment is the skill to adjust independent variables while monitoring their effects on dependents variables. This skill enables students to establish cause-and-effect relationships, a critical component of scientific reasoning (Chiappetta & Koballa as cited in Tohir, Muslim & Safira, 2021). Moreover, experimenting requires careful control of extraneous variables to ensure valid and reliable results, promoting critical thinking and problem-solving abilities in students (Simon, 2015). Experimenting also enhances students' ability to interpret and communicate findings (Kotsis, 2024). Effective experimentation involves recording observations systematically, analysing trends, and drawing conclusions based on empirical evidence (Gott & Duggan, 2007). These competencies are essential for scientific literacy, as they enable individuals to evaluate claims and make informed decisions based on evidence (Yacoubian, 2018).

Some students have shown that frequent laboratory practical activities improve students' experimenting skills. For instance, the research by Hofstein and Lunetta (2004) demonstrated that laboratory practical activities helped students develop their hypothesis formulation and testing skills. Students learned to formulate hypotheses, design experiments to test them, and analyse and interpret the results. A study by Kanari and Millar (2004) also found that hands-on laboratory activities improved students' experimental design and control skills. Students gained knowledge about identifying and minimizing causes of error as well as designing experiments with appropriate controls. Another study by Niaz (2008) showed that students' skills in data gathering and analysis were enhanced by laboratory practical exercises. Students learned to collect and record data, and to analyse and interpret the results using statistical methods and graphical representations (Bright & Friel, 2012).

2.8.2 Measuring Skills

Measuring is a fundamental science process skill that involves the use of standard and non-standard units to determine the quantity, dimensions, or capacity of an object or phenomenon (Mulyenı, Jamarıs, & Suprıyatı, 2019). It is an essential skill in scientific inquiry, as it allows for precision, accuracy, and replicability in experiments and observations (García-Carmona et al. 2024). Measuring skills enable students to quantify their observations, compare results, and make informed conclusions, which are crucial in physics, including optics. It ensures that data collected in experiments are reliable and can be analysed effectively. According to Harlen (as cited in Ramadhan et al. (2019), measuring is one of the basic process skills that contribute to the development of higher-order science skills, such as hypothesizing, experimenting, and interpreting data. In physics, particularly in optics, measuring skills are critical for determining properties such as wavelength, focal length, and intensity of light. Research as shown that laboratory practical activities provide students with hands-on experience in measuring various physical quantities, such as length, mass, volume, and temperature (Snetinová, Kácovský & Machalická, 2018). Research has also shown that these activities improve students' measurement skills. For instance, a study by Lunetta et al. (2007) found that hands-on laboratory activities improved students' measurement skills, including accuracy and precision. Students learned to use various instruments and tools to collect data, and to estimate and calculate measurement uncertainties. Another research by Hofstein and Lunetta (2004) also demonstrated that laboratory practical activities helped students understand the importance of instrumentation and calibration in measurement. Students learned to use and calibrate various instruments, such as thermometers, barometers, and spectrophotometers. A study by Jiang et al. (2023) also found that hands-on laboratory activities improved students' data analysis and interpretation skills. Students learned to collect and record data, and to analyse and interpret the results using statistical methods and graphical representations.

2.8.3 Observing skills

A key component of scientific investigation is observation, which serves as the foundation for gathering data and developing hypotheses. Using one or more senses to learn about a thing, occasion, or occurrence is called observation (Sari et al., 2023). Because it allows students to gain an understanding of scientific concepts by direct involvement with their surroundings, it is a crucial step in science education (Lunetta, Hofstein, & Clough, 2007). Effective observation requires careful attention to detail, accuracy, and the ability to differentiate between qualitative and quantitative observations (Borich, 2016). Mastery of these observational skills enhances students' ability to interpret scientific phenomena and draw meaningful conclusions (Ango, 2002). Additionally, classification, inference, and prediction are only a few of the science process abilities that are intimately related to observational skills (Gizaw & Sota 2023). For example, scientists frequently categorize items according to their observed properties, deduce correlations between variables, and forecast future events based on patterns found via observation. These skills are particularly crucial in physics optics, where precise observations of light behaviour, reflection, and refraction contribute to a deeper comprehension of optical principles (Lipson, Lipson & Lipson, 2010). Developing observation skills requires regular practice, which can be facilitated through frequent laboratory activities. According to Hofstein and Lunetta (2004), hands-on laboratory experiences significantly enhance students' observational abilities, enabling them to engage in authentic scientific investigations. Moreover, structured frequent laboratory practical activities encourage learners to refine their observational techniques by prompting them to record detailed, systematic, and accurate observations (National Research Council, 2012). Frequent laboratory practical activities provide students with opportunities to observe and record phenomena, developing their observation and recording skills. Research has shown that these activities improve students' observing skills. A study had found that hands-on laboratory activities improved students' observation techniques (Schwichow et al. 2016). Students learned to use various instruments and tools to observe and record phenomena, such as microscopes, telescopes, and cameras. A research by Hofstein and Lunetta (2004) demonstrated that laboratory practical activities helped students develop their recording and documentation skills. Students learned to record and document their observations using various methods, such as note taking, drawing, and photography. Lunetta et al. (2007) also found that hands-on laboratory activities improved students' attention to detail. Students learned to carefully observe and record phenomena, and to identify and record important details (Arias & Davis, 2016).

2.8.4 Communicating skills

For students to actively participate in scientific research, science process skills are crucial competences (Gizaw & Sota, 2023). Among these, communication skills are crucial as they allow scientists and students to share ideas, interpret findings, and collaborate in problem-solving processes (Zeidan & Jayosi, 2015). Effective communication in science involves verbal, written, and visual forms, each playing a significant role in scientific discourse and education (Nielsen, 2013).

The ability to accurately explain observations, present findings coherently, and participate in meaningful discussions with peers are all examples of communication skills in the context of science process skills (Glynn & Muth, 2008). This skill is fundamental in ensuring that scientific knowledge is transmitted clearly and can be validated or challenged by others. For instance, in laboratory activities, students must articulate their observations and results in lab reports, which demand precision and clarity (Lederman, Lederman & Antink, 2013). Moreover, scientific communication includes the interpretation and use of scientific symbols, graphs, and tables (Bybee, 2011). The ability to construct and interpret graphical representations of data is a critical component of communication in science, facilitating an understanding of concepts (Bright & Friel, 2012). Additionally, engaging in scientific argumentation, where students defend their conclusions based on empirical evidence enhances their critical thinking and reasoning abilities (Giri & Paily, 2020). The importance of communication skills in science education is also emphasized in inquiry-based learning approaches. These methods provide a more stimulating and compelling learning environment by requiring students to work together, share their theories, and clarify their thought processes (Constantinou, Tsivitanidou & Rybska 2018). Through frequent laboratory practical activities, students refine their ability to communicate scientific ideas effectively, reinforcing their acquisition of science process skills. Communication skills are integral to science process skills as they enable the accurate sharing and validation of scientific knowledge. By fostering strong communication abilities, educators can enhance students' engagement and proficiency in scientific inquiry. Some evidence show frequent laboratory practical activities provide students with opportunities to present and discuss their findings with peers, developing their communication skills. For instance, a study by Kanari and Millar (2004) found that hands-on laboratory activities improved students' oral presentation skills. Students learned to present their findings clearly and concisely, using visual aids and props to support their presentations. This finding was not different from what was indicated by Hofstein and Lunetta (2004) who demonstrated that laboratory practical activities helped students develop their written communication skills.

2.8.5 Inferring skills

Science process skills are necessary for scientific inquiry, fostering critical thinking and problem-solving abilities. Among these, inferring skills play a vital role in interpreting data and making logical conclusions based on observations. Inference is the capacity to derive meaning beyond direct observation by using prior knowledge and evidence (Boghossian, 2014). Inferring skill is a foundational skill in scientific reasoning and is integral to hypothesis formulation and experimental analysis (Bhagyamma & Wasiq, 2023). As indicated in a study by Aggelopoulos (2015) inferring involves interpreting observations to explain an event or predict an outcome. Unlike direct observation, which relies on sensory perception, inference depends on cognitive processing and prior knowledge. For instance, in physics optics experiments, when students observe light bending as it passes through different media, they infer the concept of refraction without directly seeing the light rays change direction. Research suggests that frequent engagement in laboratory activities enhances students' inferential reasoning by providing opportunities to practice data interpretation and hypothesis testing (Demaria, Barry & Murphy as cited in Antonio & Prudente, 2024). Hands-on experimentation allows students to refine their inferring skills through trial and error, reinforcing their understanding of scientific principles (Bybee, 2011). Moreover, developing strong inferring skills is crucial for scientific literacy, as it enables students to analyse information critically and draw evidence-based conclusions (Sutiani, 2021). Inferring skill is particularly important in modern scientific investigations where indirect measurements and theoretical models are commonly employed (Zimmerman, 2007). Inferring is a critical science process skill that enhances students’ ability to analyse, predict, and explain scientific phenomena. Encouraging its development through frequent laboratory activities can significantly improve students’ scientific reasoning and overall comprehension of physics concepts.

Frequent laboratory practical activities provide students with opportunities to make inferences and draw conclusions from data, developing their scientific reasoning skills. Research has shown that constant laboratory practical activities improve students' inferring skills. For instance, Research by Etkina et al. (2010) demonstrated that laboratory practical activities helped students develop their pattern recognition skills. Students learned to identify patterns in data, and to make inferences and draw conclusions based on those patterns. As indicated in Owusu (2022), hands-on laboratory activities improved students' causal reasoning skills. Students learned to identify cause-and-effect relationships in data, and to make inferences and draw conclusions based on those relationships. Hofstein and Lunetta (2004) also indicated that laboratory practical activities helped students develop their predictive reasoning skills. Students learned to make predictions based on data, and to test and refine those predictions through experimentation.

2.9 Organisation of Frequent Laboratory Practical Activities

The structured activities and supervision of experiments and hands-on activities carried out in a laboratory setting are referred to as laboratory practical activity organization. This includes designing experiments, scheduling lab lessons, assigning roles and responsibilities, ensuring safety protocols are followed, and providing resources and guidance to participants ensuring that the students get the required amount of time for the practical activities. For a successful organisation of laboratory practical activities, some researchers outlined the following steps:

i. The teacher must ensure that the laboratory activities directly relate to the learning objectives outlined in the curriculum (Brown et al., 2020). The practical activity must be aligned with specific physics topics to provide context and relevance to students' learning experiences.

ii. The teacher must design a coherent sequence of laboratory activities that follows a logical progression (Johnson, 2019). The teacher must start with simple experiments to introduce fundamental concepts and gradually increase the complexity to challenge students' understanding and skills.

iii. To get students ready for the impending experiments, the instructor needs to give them pre-lab materials (Smith & Jones, 2018). Students may be introduced to the theoretical foundation and experimental methods through reading assignments, internet resources, or multimedia resources.

iv. The teacher must organise the laboratory space efficiently, ensuring that all necessary equipment and materials are readily available (Kozub et al. 2021).

The teacher must clearly label materials and provide detailed instructions to facilitate smooth transitions between experimental setups (Schneider, Krajcik & Blumenfeld, 2005**).**

v. The teacher must begin each laboratory session with a comprehensive demonstration of the experiment. Explain the underlying principles, relevant theories, and experimental techniques to provide students with a clear understanding of the objectives and procedures(Lunetta, Hofstein & Clough, 2013)

vi. The teacher must motivate students to proactively engage in hands-on experimentation (Lee, 2018). The teacher must provide opportunities for students to manipulate equipment, make observations, and collect data independently, fostering a sense of ownership and inquiry-driven learning.

vii. The teacher must guide students through the process of collecting, recording, and analysing experimental data (Hopkins, 2014). The students must be taught how to use appropriate measurement techniques, organize data effectively, and interpret results accurately using mathematical and statistical tools (Van Blerkom, 2008).

viii. The teacher must facilitate meaningful discussions and reflection activities following the completion of experiments. Students must be encouraged to critically analyse their findings, identify sources of error, and propose explanations based on scientific reasoning and evidence (McNeill & Krajcik, 2008).

ix. The teacher must emphasize the integration of laboratory activities with theoretical concepts taught in the classroom. Students must be assisted in identifying the connections between their experimental observations and the underlying principles discussed in lectures, promoting an understanding of the subject matter (Barron, 2014).

x. The teacher must implement various assessment methods to evaluate students' performance in laboratory activities. Provide timely and constructive feedback to guide students' learning and skill development (O'Brien, 2023). Following these points, teachers can develop a comprehensive framework for organizing frequent laboratory practical activities effectively, promoting the acquisition of science process skills among students in physics.

2.10 Teaching Methodologies in Science Education

The primary aim of teaching any subject is to bring about the desired changes in students' behaviour. Such changes are reflected in students' ability to learn effectively. At the Senior High School (SHS) level, subjects like biology, chemistry, and physics are taught both separately and as part of integrated science, which is mandatory for all students. The SHS science curriculum employs a variety of instructional approaches. Mitchell (2015) emphasized that teachers are expected to use a range of instructional strategies that promote academic success for all science students. For a teaching method to be effective in the current educational context, it should encourage maximum social interaction. Learning, to a large extent, relies on social engagement among students and between teachers and students (Nguyen, Williams & Nguyen, 2012).

These writers also emphasized how important it is to give pupils a safe, transparent, and engaging atmosphere because it may aid in their learning. The lecture technique, demonstration method, project method, observation method, discovery method, practical method, and role-play are the teaching strategies most frequently employed in science education classes (Cimer, 2007).

1. Students are frequently given a lot information in a short amount of time using the lecture technique (Berry, 2008). Similar observation was made by Hontarenko and Kovalenko, (2024) that lecture method enables the teacher to present information clearly and concisely and allow to organise and present information in a logical and structured way, making it easier for students to understand and follow along. As indicated by Sandhu, Afifi and Amara (2012) lectures are designed to deliver a piece of new information to a large group of students**.** However, research has also identified that the lecture method commonly used does not help the students acquire sufficient functional understanding (Bernhard et al., 2007). Covill (2011) cited that the lecture method lacks the effectiveness of an active learning approach. The lecture method can be a passive approach to learning, where students are simply receiving information without actively engaging with it. (Bonwell, 2000). The lecture method may not engage students fully, as they may not be actively participating in the learning process which could lead to a lack of understanding and retention of material (Arora, 2017). The lecture method may not accommodate different learning styles, as it typically involves a one-size-fits-all approach to teaching (Kumar, 2016).
2. Demonstration method is a useful method of teaching because it improves students' understanding and retention (McKee, Williamson & Ruebush, 2007). Al-Rawi (2013) asserts that scientific laboratory activities and instrument usage abilities can be effectively taught through demonstration. A greater comprehension of the subject matter results from demonstrations, which aid students in visualizing and making sense of abstract ideas as well as complex concepts (Basheer et al. 2016). By seeing demonstrations, students can connect

theoretical concepts to real-world applications, making the material more meaningful and relevant (Kumar, 2016). Demonstrations can be engaging and interactive, motivating students to learn and participate in the learning process and encourage students to ask questions, think critically, and engage in hands-on learning. Nevertheless, there is not much time in a classroom to complete this demonstration. Consequently, a demonstration is frequently created to let students observe instead of using a practical laboratory (McKee et al., 2007). Additionally, McFarland discovered that when students participate more actively in the demonstration and begin to raise questions regarding the science material, the nature of classroom engagement tends to be less one-way. Demonstrations can be difficult to conduct in large classes, where it may be hard for all students to see and participate (Germann, 2017). Demonstrations often demand specific equipment and materials, which can be expensive and difficult to obtain.

3. The laboratory method of teaching science is considered a hands-on and minds-on approach to teaching science where students have the opportunity to gain some experience with phenomena associated with their course of study (Spaan et al. 2024). In this method either students participate alone or in small groups. They create or alter different factors that are being investigated.
4. The project method is also another method of teaching science. According to Krajcik and Czerniak (2018), this approach focuses on creating a whole unit around an activity that can be done both inside and outside of the classroom. The core of this approach is that students work together to complete a certain assignment. This suggests that students work on the task for a while, either independently or in groups. According to Shamsudin, Abdullah, and Yaamat

(2013), groups of no more than three students are ideal, and they must come up with a project for their discovery content. Hussain, Azeem, and Shakoor (2011) also assert that project-based learning improves students' academic performance and enables them to comprehend science subjects more deeply. It also enables learners to engage in the processes of evaluating the science content to be learned, anticipating how that knowledge would be used, as well as applying the science content in authentic situations (Kanter, 2010). Project activity also helps teachers in the creation of their science content knowledge (CK) as well as their science Pedagogical Content Knowledge (PCK) as they prepare and facilitate students' work (Kanter & Konstanntopoulos, 2009).

5. Simulation in teaching involves the use of role-play, games, and models. Falloon (2019) explained that simulation using a model represents a form of experiential learning**,** where the teacher creates a controlled learning environment for the students. Within this simulated setting, learners engage as if they are the test subjects in a laboratory experiment. This approach aligns closely with the principles of constructivism and provides an effective means for students to grasp the subtleties of a concept or situation.The investigation conducted as indicated by Guy and Lownes-Jackson (2015) on students' chemistry performance shows that those who were taught using computer-based science simulations attained better scores than those who were taught using traditional instruction methods.

In many instances, it is prudent to combine different teaching methods to achieve a positive result as indicated by Cimer (2007). According to Arora (2017), combining the lecture, demonstration, and laboratory methods can enhance students learning and understanding in the study of physics. The use of the right method or combination of different teaching methods as well as keeping in mind the capability of the students and the objective of the curriculum are very useful in achieving the aims of science education (Mohan, 2019). Thus, the method is a way of presentation of the content in the classroom. But, it is, however, very important to keep in mind that a method is not an end in itself but is used to achieve the set aims of teaching. It is important to remember that the same approach should not be applied consistently; rather, it should be applied with flexibility when the conditions, circumstances, and scenarios in a given case vary (Yin, 2003). Science teachers should use various methods of teaching depending on the demands of the situation (Shamsudin, et al., 2013). These various teaching methods when used well will help achieve positive results and equip the students with the science process skills for the future (Zorlu & Sezek, 2020). However, in this study, the researcher is interested in investigating the effect of frequent laboratory practical activities on the acquisition of science process skills of physics students in optics.

2.11 Empirical Studies on Laboratory Practical Activity in Science Education

In countries with a strong tradition of practical activities in school science, such as the United Kingdom, teachers and other stakeholders, particularly scientists, often view laboratory work as central to the appeal and effectiveness of science education (Hofstein & Kind, as cited in Abrahams, Reiss & Sharpe, 2013). Laboratory activities help students deepen their understanding of scientific concepts, recognize that science is evidence-based, and acquire the practical skills essential for scientific progress (Asheela, 2017). Teachers are encouraged to provide students with engaging and diverse experimental and investigative experiences.

As noted by Osborne (2007), Roberts highlights that the availability of qualified individuals in science, technology, engineering, and mathematics (STEM) is strongly influenced by the quality of school science laboratories. Believing that well-equipped labs reflect the professional world of science and technology and can inspire students to pursue STEM fields, the reports recommend that governments and local education authorities prioritize funding to upgrade school laboratories to a good or excellent standard. Students' laboratory experiences play a critical role in motivating them to continue their studies in science. For example, students in Scotland reported that laboratory work enhanced both their practical skills and theoretical understanding (Hanif et al., 2008).

Kibirige, Rebecca, and Mavhunga (2014) conducted a quasi-experimental study using pre- and post-tests to examine the effect of practical activities on students' science performance. The study involved sixty students, with thirty in the experimental group receiving hands-on instruction and thirty in the control group taught without practical activities. Results from pre- and post-tests indicated that students in the experimental group outperformed those in the control group. The experimental group had an average score of M = 22.8 (SD = 6.50), compared to the control group's M = 11.3 (SD = 3.0). ANCOVA analysis confirmed that the improvement was attributable to practical activities, and a t-test revealed a statistically significant difference between the two groups ($t(58) = 8.63$, $p < .05$). A Mann-Whitney U test further showed no significant difference between boys' and girls' performance in the experimental group. These findings suggest that hands-on learning enhances student performance, indicating that the integration of practical activities in teaching Physical Sciences can improve learner achievement.

Similarly, Sshana and Abulibdeh (2020) conducted a quasi-experimental study to assess the impact of practical activities on students' academic achievement in science. The study involved tenth-grade biology and chemistry students and eleventh-grade chemistry students, divided into control and experimental groups. While the experimental groups received teaching with extensive practical exercises, the control groups were taught using conventional methods. Pre- and post-tests revealed that the experimental groups significantly outperformed the control groups. Based on these results, the researchers recommended that secondary schools provide students with regular opportunities for hands-on learning and ensure that laboratories are adequately equipped to support effective practical activities.

Antwi, Sakyi-Hagan, Addo-Wuver, and Asare (2021) also investigated the effects of practical activities on students' academic achievement, acquisition of science process skills, and attitudes toward selected topics in electricity, further supporting the positive impact of hands-on learning in science education.

A study involving fifty (50) Form Two Physics students from a Senior High Technical School was conducted in Kwaebibirem Municipality, Eastern Region, Ghana. A questionnaire, pre- and post-intervention exams, and a student learning evaluation form were among the tools used to gather data. Descriptive statistics and Microsoft Excel 2010 software were used to analyse the data. The results showed that exposing students to laboratory practical activities improved their academic performance. According to the report, physics instructors should use practical activities as a teaching method and be urged to include concepts into their lessons. Shana and Abulibdeh (2020) carried out a similar study to assess the overall impact of practical activities on students' academic achievement in science. Students in the chemistry and biology tenth and eleventh grades were chosen as participants, and they were split into control and experimental groups. While the experimental groups received the same material through intense hands-on activities, the control groups received instruction using conventional techniques. All groups were given pre- and post-tests. A comparison of mean scores showed that the experimental groups had a considerable advantage. The researchers suggested that secondary schools provide students with regular opportunity to participate in hands-on activities. Again, similar studies were carried out by Musassia, Acholla, and Sakwa (2016) to ascertain whether organized hands-on activities can facilitate physics learning. The study specifically aimed to determine how students who were taught physics through extensive practical exercises fared academically compared to those who were taught using traditional teaching techniques, which primarily involved theory. Two groups from average-performing secondary schools in Kenya's Kakamega South Sub-County were sampled for the study. The study used a quasi-experimental pre-test and post-test non-equivalent group design. Terms two and three were covered during the study session. The pre-test consisted of the results of the physics exam from the end of form two-term one. The post-test for both groups was created using the total scores on the selected subjects at the conclusion of form two. Data was gathered using two instruments. Both the experimental and control groups performed similarly on the pre-test results. The t-test, Analysis of Variance, and Chi-Square were used to analyse the post-test data. Compared to the control group, the experimental group performed better. Determining the importance of experimenting in physics education was another benefit of the study. It is intended to contribute to the development of policies about the type and calibre of hands-on activities in the teaching of physics in secondary schools.

Etiubon and Udoh (2017) conducted another study whose results demonstrate the crucial significance that practical practice plays in academic performance. In the Uruan Local Education Authority of Akwa Ibom State, they carried out a study to look into how science students' academic performance on solubility was affected by practical exercises and the manual. Pre-test, post-test non-randomized quasi-experimental design was used in the study. The study's conclusions showed that when students were taught the idea of solubility through hands-on exercises and a practical handbook, their performance improved dramatically. Therefore, using instructional materials for hands-on activities to improve students' academic performance is crucial to providing effective and high-quality instruction both inside and outside of the classroom.

Chukelu (2009) also looked into how biology hands-on activities affected the development of process skills in Abuja Municipal Area Council students. The study's pre-test, post-test, and non-equivalent control group designs were all quasi-experimental. One hundred and eleven senior secondary biology students—60 males and 51 females, from two senior secondary schools in the Abuja Federal Capital Territory's municipal area council education zone made up the sample. The study was led by three hypotheses and three research questions. The experimental group was taught a chosen biology concept called "Animal nutrition" through a practical activity technique, while the control group received the identical instruction through a lecture. The Science Process Skill Acquisition Test (SPSAT) designed by the researcher, was the instrument used for data collection. The study concerns were addressed by analysing the data using mean and standard deviation, and the hypothesis was tested at the 0.5 level of significance using analysis of covariance (ANCOVA). The findings showed that students' acquisition of science process abilities was better supported by the practical activity technique than by the lecture method. Additionally, there is proof that, in comparison to other science teaching and learning activities, students find practical activities to be both pleasant and beneficial. In a poll of more than 1,400 students, 71% selected "experimenting in class" as one of the three approaches to teaching and learning science that they found "most enjoyable" (Cerini, Murray & Reiss as reported in Hampden-Thompson & Bennett, 2013). It was chosen by a smaller percentage (38%)

as one of the three science teaching and learning strategies they thought were "most useful and effective."

Some researchers have reported that practical activities can increase students' sense of ownership of their learning and can increase their motivation (Reid & Shah, 2007)**.**

In a comparative research, Thompson and Soyibo (2002) documented the beneficial effects of a mix of lectures, instructor demonstration, discussion, and hands-on activities on the attitudes toward chemistry and electrolysis comprehension of 10th-grade Jamaican students (ages 15–16).

Freedman (as cited in Deehan, MacDonald, & Morris, 2024) investigated the influence of a hands-on science curriculum on students' attitudes and academic achievement. The study found that students aged 14 to 15 who regularly participated in laboratory practical activities**:** (a) achieved significantly higher scores ($p < .01$) on an objective test of science knowledge compared with those who did not experience laboratory instruction; (b) demonstrated a moderately positive correlation ($r = .406$) between their academic achievement and their attitudes toward science; and (c) continued to perform significantly better ($p < .01$) in science achievement even after controlling for the effect of attitudes toward science as a covariate.

Akinbobola and Afolabi (2010) examined the science process abilities in the physics practical test for the West African Senior Secondary School Certificate in Nigeria during a ten-year period (1998-2007). For the study, the expo-facto design was used. The study was led by one null hypothesis and two research questions. The physics practical accomplishment test questions (PPQ) served as the data collection tool. Practical questions in physics were used as the data collection strategy. To analyse the data, percentages were employed. The study revealed that five out of the fifteen major science process skills were developed. These included manipulating (17.20%), calculating (14.20%), recording (13.60%), observing (12.00%), and communicating (14.40%). Laboratory practical activities, which have long been considered an essential aspect of science education, provide students with direct experiences that help improve their understanding of scientific concepts.

Lunetta et al. (2007) also concluded from their research that laboratory experiences in science education place students in different levels of inquiry, requiring them to engage both mentally and physically in ways that are not usually possible in other learning situations. It goes on to suggest that practical activities bring in behaviour changes in the students. This shift is based on the scientific temperament, curiosity, interest, and inventiveness. Through shown techniques, practical exercises aim to provide a body of knowledge. In the Patani local government region of Delta State, Asiyai (2006) studied how pupils in public and private secondary schools learned science process skills in chemistry. Two hypotheses were developed and examined in the study, along with two research questions. The study employed the ex post facto research design. A sample of one hundred students studying chemistry was selected from ten schools located in urban and rural settings in the local government area. Findings showed that both male and female students have low levels of acquisition of measuring, inferring, and predicting science process skills with female students having a higher level of acquisition of communicating skills than male students. Results based on school location showed that pupils in urban schools learn chemistry scientific process abilities more effectively than those in rural schools. The study's conclusion suggested that schools make sure to regularly expose students to chemistry practicals in order to raise their understanding of the science process skills in the subject. Additionally, in order for pupils to have sufficient knowledge of chemistry scientific process abilities, practical classes should begin as early as possible.

Another study by Falemu and Akinwumi (2021) looked at how biology practical exercises affected secondary school learners' academic achievement in the Ikere Local Government Area of Ekiti State, Nigeria. One hundred and twenty-five (125) students were selected from the study population using basic sampling techniques to make up the sample. Questionnaires served as the study's data gathering tools, and the mean and standard deviation were used for analysis. According to the findings, students learn more effectively when they participate in real-world experiments, which aligns theory with practice. Practical biology exercises foster critical thinking, creativity, and curiosity. Additionally, they recommended that students be encouraged to approach every practical biology assignment with great seriousness. In order to improve student accomplishment, they concluded by recommending that school administrators hire laboratory technicians to help biology teachers with practical activities. This would ensure that workload, time management, and regular practicals are feasible.

Furthermore, a study by Oladehinde (2023) looked at how senior secondary school students performed when learning biology process skills in the context of hands-on laboratory activities. The findings showed that students who were exposed to hands-on laboratory activities outperformed those who were taught through lectures in terms of acquiring science process skills. In a similar vein, Okam and Zakari's (2016) study looked at how laboratory-based teaching methods affected students' development of chemistry scientific process abilities. According to the study's findings, laboratory-based pedagogies are useful for helping students learn science process skills, and educators are encouraged to use them to help students develop their skills.

Apeadido et al. (2023) looked into how practical activities affected biology students' academic performance and science process skills. According to the study, adding hands-on activities to biology classes helped students learn and grow their science process abilities, which in turn helped them perform better academically. Efe and Abamba(2023) also carried out similar study (2023) to look into how laboratory techniques affected the way senior secondary school chemistry students learned science process skills. The investigation was guided by three hypotheses. A non-randomized pre-test, post-test control group quasi-experimental design was used for the investigation. Using stratified random sampling, six secondary schools were chosen. In the study, three schools were assigned to the control group while the remaining three formed the experimental group. The sample comprised 189 students drawn from six intact classes. Two instruments were used for data collection: the Chemistry Process Skills Rating Scale (CPSRS) and the Chemistry Practical Ability Test (CPAT). The findings showed that, compared with the lecture method, the laboratory approach significantly enhanced students' acquisition of science process skills in both quantitative and qualitative analyses. The results further indicated that students developed more science process skills during quantitative analysis than in qualitative analysis, with the laboratory method contributing approximately 74% to the development of these skills. Based on these findings, the researchers recommended the consistent use of the laboratory approach when teaching practical aspects of chemistry. They also suggested that chemistry practical activities should begin in Senior Secondary School One and be scheduled for specific periods each week, rather than waiting until Senior Secondary School Three before introducing students to practical components.

Similarly, Nneji et al. (2024) carried out a study to examine the effect of practical work experience on the academic performance of senior secondary school biology students in Yenagoa Metropolis. Two public secondary schools were randomly selected for the study. From each school, one intact class was randomly chosen and assigned to either the experimental or control group. Out of 256 biology students enrolled in Senior Secondary I (SSI) in the selected schools, 219 formed the sample for the study. The researchers employed a quasi-experimental pretest–posttest design. While the control group was taught using a modified lecture method, the experimental group received instruction through a practical activity experience approach. The Biology Achievement Test (BAT**)** was used as the instrument for data collection. The study was guided by two research questions and two hypotheses, which were tested at a significance level of 0.05. When t-test statistics were applied to mean score differences, they were shown to be gender-friendly and significant in favour of the experimental group. To encourage science instructors to use practical activity experience techniques in the teaching-learning process in schools, it was suggested that they be given practical allowances. A descriptive survey design was used to investigate the impact of physics laboratory activities on senior high school students studying physics in the Ethiope West Local Government Area of Delta State. Five public schools were selected using a random-even sampling technique to ensure accuracy. To minimize possible data manipulation, 50 questionnaires were distributed in each school, resulting in a total of 250 students participating in the study. The questionnaires were collected immediately after completion. The data obtained were analysed using percentage analysis. The findings indicated that 80.4% of the respondents agreed that the physics laboratory supports the teaching of physics to senior high school students in Ethiope West L.G.A. of Delta State, while 19.6% disagreed. Furthermore, 87.2% of the students believed that physics practical activities improve learning and have a positive impact, whereas 12.8% expressed a contrary opinion.

. The statements that there is a significant relationship between students and teachers during experimental classes, that physics laboratories help instil scientific reasoning in physics students, and that physics laboratories improve students' performance in physics in senior secondary schools in Ethiopia West L.G.A. of Delta State were the ones that 92.2%, 75.9%, and 88.3% agreed with, while 7.8%, 24.1%, and 11.7% disagreed with. Amunga, Amadalo, and Musera (2011) show that the students take science learning seriously as a result of the practical exercise. The student takes control of the learning environment and gains insight into the requirements of the task at hand as a result of their determination to fulfil the physics objectives and practical task requirements. According to Lunetta et al. (2007), science practical activities offer simulation experiences that place students' learning in inquiry-based states that require a high level of mental and physical engagement. It has also been discovered that girls greatly benefit from gender-specific practical activities (Amadalo, Sulungai & Toili, 2012). After integrating practical activities into the girls' curriculum, their performance on physics achievement assessments improved.

However, despite these numerous positive effects, the findings of some studies point out some contrasting views about laboratory-based teaching on the acquisition of science processes. According to Hofstein and Lunetta (2004), frequent laboratory practical activities may lead to students relying heavily on recipe-like procedures without grasping the underlying scientific principles. This can hinder students’ ability to apply their knowledge in novel situations or to transfer their skills to real-world contexts. Moreover, overcrowded laboratory activity may result in decreased individual engagement and hands-on experience for each student, diminishing their opportunity for skill development (Bennett & Lubben, 2006). Additionally, the pressure to complete experiments within limited periods may foster a superficial understanding of scientific processes, rather than encouraging deeper inquiry and exploration (Neuman, 2008). In crowded laboratory settings, students may not receive adequate individualized attention from instructors, limiting opportunities for personalized feedback and guidance. This lack of attention can impede students' ability to identify and correct misconceptions or errors in their understanding (Hofstein & Lunetta, 2004). Strict adherence to prescribed laboratory procedures may stifle students' creativity and experimentation. Students may feel limited in their capacity to consider alternate approaches or critically analyse the scientific method if they are continuously following a pre-set set of steps (Bennett & Lubben, 2006). Frequent laboratory practical activities require careful supervision to ensure student safety. However, in fast-paced environments with limited instructor oversight, there is an increased risk of accidents or mishaps that could deter students from fully engaging in the learning process. Frequent lab exercises might sometimes put more emphasis on reproducing pre-existing experiments than on motivating students to plan and carry out their own research. Students may end up studying passively as a result, only following directions without actively pursuing scientific research (Hofstein & Lunetta, 2004). Continuous exposure to laboratory activities without sufficient variation or novelty may lead to student disengagement and decreased motivation. When students perceive laboratory sessions as repetitive or monotonous, they may lose interest in the subject matter and become less motivated to develop their science process skills (Bennett & Lubben, 2006).

Some recent research has challenged the conventional wisdom regarding the effectiveness of frequent laboratory practical activities in enhancing student-learning outcomes. Contrary to the prevailing belief, Abrahams (2009) conducted a study on the affective value of practical activities in secondary school science and found out that though it is frequently asserted that practical action fosters short-term engagement, it is comparatively inefficient in fostering longer-term personal interest in the subject or motivation to study science after being forced to. Furthermore, the study recommended that people working in scientific education cultivate a more realistic awareness of the limitations of affective domain practical activities. While students may excel in executing experiments within the controlled environment of the laboratory, they often struggle to apply their learning to practical situations beyond the classroom walls. This disconnect underscores the need for instructional approaches that bridge the gap between theory and application in science education. Okinuga, Ojo, and Yande (2013) conducted a study to assess science process skills acquisition of Basic science students in Junior Secondary Schools 3 also confirmed these contrary views. This study used a descriptive survey design. Eight categories of science process abilities were studied, and the study was led by three research objectives and one null hypothesis. Their study's findings demonstrated that students' development of science process abilities is lacking. But out of all the science process skills, classification was the most learned, and the only one that was proficient in the field was measuring and applying numerical relations. Additionally, the study found that children struggled to learn process skills like communicating, predicting, interpreting, inferring, observing, and experimenting. Abraham and Millar (2008) acknowledged in another study that teachers' emphasis in practical lessons was primarily on helping students acquire substantive scientific knowledge rather than an awareness of scientific inquiry methods. They maintained that while practical exercises were often successful in getting students to utilize physical objects as intended, they were far less successful in helping them apply the desired scientific concepts to direct their behaviour and think critically about the data they gathered. Additionally, Lunetta, Hofstein, and Clough (2007) contended that students build knowledge by resolving real-world, significant challenges. Their results imply that assignments that seem to have a purpose related to students' everyday lives may produce higher-quality performance than practical exercises that lack context and are only designed to test students' practical skills or abilities.

According to Minner, Levy, and Century (2010), students cannot develop sophisticated conceptual understandings of the modern scientific community through laboratory research alone. Intervention and negotiation with an authoritative figure, typically a teacher, are crucial if pupils' understandings are to shift toward those of recognized science. For instance, Abrahams (2011) asserts that practical activity is misguided, unclear, and ineffective as it is implemented in many schools. For many kids, the activities that take place in the lab do not really help them learn science. According to Craciun (2010), role-plays can allow students to physically experience a variety of events, which may be more suitable for their preferred method of learning. Students are able to comprehend challenging and complex subjects that are not usually obvious occurrences as a result. Additionally, according to Blatner (2009), role-playing is preferred by instructors, trainers, or supervisors as a convenient way to add interest to the course material. Researchers such as Minner, Levy, and Century (2010) and Abrahams (2011) also have different views when it comes to the benefits and role of laboratory practical work in science education. They are of the view that practical activity as practiced in many schools is ill-conceived, confusing time-consuming, expensive, and expensive as compared to other methods of teaching. Others such as Craciun (2010) and Lekhi and Nussbaum (2015) believe that other teaching methods such as role-play are more useful than laboratory practical activities.

The views and suggestions of many researchers clearly show that laboratory activities could be beneficial or not beneficial to both the students and the teacher depending on how it is utilised.

The emergence of these contrary findings has significant implications for science education practice and curriculum design. Addressing these potential negative effects, educators can strive to create more balanced and effective laboratory experiences that promote meaningful skill development and a deep understanding of scientific concepts.

Despite the acknowledged importance of optics and science process skills, the specific problem addressed by this study is the low acquisition of key science process skills among senior high school students, largely resulting from infrequent and poorly structured laboratory practical activities in optics and the absence of context-specific assessment tools to systematically evaluate these skills. This lack of focused practical engagement and assessment has limited students' ability to effectively observe, measure, experiment, infer, and communicate during optics lessons, thereby justifying the need for the present study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter describes the research design and the procedures the researcher adopted to address the stated research questions. It also presents the location where the study was conducted. In addition, the chapter discusses the population of interest, the sample, and the sampling technique used in the study. The instrument used for data collection is also described. Furthermore, the chapter explains how the validity and reliability of the instrument were established, as well as the methods used for data collection and data analysis.3.1 Research Design

Dannels (2018) defines research design as a strategy or plan the researcher employs to address the study issue or questions. A study's design, according to Polit and Hungler (as stated by Hoe & Hoare 2012), provides a picture of what happened and helps to explain people's beliefs and actions based on information acquired at a specific moment in time. This study was action research designed to use frequent laboratory practical activities to develop the science process skills of students. Cohen, Manion, and Morrison (2017) explain that action research is a systematic study that combines action and reflection to improve practice. Craig (2009) further explained that action research is a process in which practitioners study problems scientifically so that they can evaluate, improve, and steer decision-making and practice. Action research was selected for these reasons and the study's goals because it would help teachers improve their classroom practices, boost student learning, and support their professional and personal development (Cabaroglu, 2014).

Action research is intended to address practical problems that occur within a learning environment. Consequently, action researchers concentrate on real-life issues that can lead to immediate improvements in education. It focuses on identifying a specific problem in practice and seeking appropriate solutions to it (McNiff, 2013; Cohen, Manion & Morrison, 2018). Cohen, Manion, and Morrison (2018) further explained that action research aims to close the gap between research and practice. They added that the primary objective of action research is to bring about practical improvement, change, or development in social practice while also enhancing practitioners' understanding of their own professional practices.

Investigating a particular educational experience in order to enhance practice is the aim of practical action research. Action research usually consists of a small-scale study carried out by teams or individual teachers inside a school or district, with a narrow emphasis on a particular topic or issue (cited in Basnet, 2019). It enables researchers to plan, implement, review, and evaluate interventions aimed at improving practice or solving local problems. Creswell (quoted in Ivankova, 2015) asserts that action research can be applied in nearly any context where there are issues with people, tasks, or procedures and where advancements can result in better outcomes. Action research is deemed to be suitable for this study because of these features.

3.2 Research Approach

This study used a quantitative research approach, which involves collecting and analysing numbers and facts in an objective way (Creswell, 2014). According to Mumba and Alici (2021), quantitative research is about gathering numerical data and using it to understand patterns, compare groups of people, or explain specific issues. The goal of this study was to collect numbers and data to show how frequent laboratory practical activities improve students’ science process skills in selected topics in optics.

3.3 Study Area

The study was carried out at Begoro Presbyterian Senior High School, a coeducational public school situated in the Eastern Region of Ghana. The school was chosen mainly because it was easily accessible, which made the collection of data and the overall implementation of the study more convenient. Begoro Presbyterian Senior High School admits students from different socioeconomic backgrounds and offers several academic programmes, including General Science, General Arts, Business, Home Economics, and Visual Arts. At the time the study was conducted, the school had an estimated population of about 2,800 students. The choice of the school was further influenced by its well-structured academic programmes and the diverse nature of its student population, factors that help strengthen the external validity of the research. In addition, its accessible location made it appropriate for the smooth and efficient conduct of the study.

3.4 Research Population

A population refers to a group of individuals relevant to a particular study who share one or more common characteristics (Asiamah et al., 2017). In a similar way, Cohen et al. (2018) define the population of interest as a collection of individuals who possess certain traits or characteristics that are significant to the research. In the context of this study, the population included all General Science students at Begoro Presbyterian Senior High School.

The target population refers to the larger group of individuals or cases that the researcher intends to study or describe (Hancock et al., 2021). It comprises all individuals or units that meet the specified criteria for inclusion in the research

(Bryman, 2016). In other words, the target population represents the entire group from which the researcher aims to draw conclusions. In this study, the target population consisted of all Form Two General Science students at Begoro Presbyterian Senior High School.

An accessible population is a portion of the target population that is available and reachable for the purpose of the study (Etikan et al., 2016). It includes individuals who can be conveniently accessed and are willing to take part in the research (Nardi, 2018). Accessibility may be affected by factors such as location, availability, and participants' willingness to be involved. For this study, the accessible population comprised Form Two Physics students at Begoro Presbyterian Senior High School.

The researcher, being a teacher at the school, has observed first-hand the challenges students face in acquiring essential science process skills. These deficiencies not only adversely affect students' academic performance but also limit their capacity for critical thinking and creative problem-solving.

3.5 Sampling and Sampling Procedure

A sample is a smaller group drawn from a larger population for the purpose of a study (Delice, 2010). Similarly, Creswell and Creswell (2017) describe a sample as a subset of the population selected to participate in a research study. Sampling refers to the process of selecting units from a population of interest so that, by studying the selected group, conclusions can be reasonably generalized to the entire population (Lohr, 2021).

In this study, non-probability sampling was used to select participants in line with the objectives of the research. There are several types of non-probability sampling methods, including convenience sampling, quota sampling, purposive sampling, and snowball sampling (Cohen, Manion & Morrison, 2017).

However, the study's sample was chosen through the technique of purposive sampling. Purposive sampling, according to Cohen, Manion, and Morison (2017), is the process of choosing a sample based on the assessment of how likely it is that they will possess the specific qualities being sought. Purposive sampling, according to Opie (2019), is a method where the researcher personally selects participants for the sample based on their perceived typicality. Purposive sampling was the best method to use when choosing Form 2 science 1 physics students because the goal of this study was to examine how frequent laboratory practical activities affected the development of science process abilities in physics students. This approach selects sample members based on their expertise, connections, and knowledge of a research topic (Trochim & Donnelly, 2001).

There are two Form 2 physics classrooms, and the school has eight-eight (88) pupils in total. Form 2 Science 1 and Science 2 students were in these two classes. After giving it some thought, the researcher chose to concentrate the study on Form 2 Science 1 physics students because it was in that class that the researcher discovered students lacked the necessary science process skills. The class consisted of 53 students. The researcher thought that by choosing Form 2 Science 1 physics, it would be possible to evaluate pertinent science process abilities through frequent laboratory practical exercises and contribute significantly to the subject of study.

3.6.0 Data Collection Instrumentation

The term "data collection instrument" describes the range of methods the researcher uses to gather the information required for the study. Both qualitative and quantitative data were collected for this study. These consist of student evaluation techniques for science process skills, observation, and a 4-point Likert scale survey. The purpose of the intervention and post-intervention practical tests were to assess the degree to which students have acquired science process skills both during and after the intervention activities.

The study commenced in July 2024. The Research questions, data source, data collection instrument, and analysis techniques are summarised in Table 2.

Table 2: *Research questions, data source, data collection instrument, and analysis techniques*

Research Question	**Data source**	**Data collection instrument**	**Analysis technique**
What are the extent of science process skills of students after being exposed to frequent laboratory practical activities?	Students	Post-test intervention Results in Students' Learning Evaluation Form, checklist, and Observation	Percentages and mean values
What is the correlation between the frequency of laboratory practical activities and the acquisition of science process skills in physics among students?	Students	Post-test Intervention Results Students' Learning Evaluation Form	Percentages and mean values
What are the students' perceptions toward frequent laboratory practical activities on the acquisition of science process skills?	Students	A 4-point Likert Scale questionnaire	Mean values

3.6.1 The phases of the data collection on students' output of work

There were three stages to the data collection process about the output of work produced by the students. The senior high school physics syllabus served as a basis for the construction of the post-intervention physics practical exercises and questions, and weekly lesson plans that emphasized the development of science process skills for the students were created.

3.6.2 Pre-intervention exercise

Pre-intervention activities refer to the actions taken by researchers before implementing an intervention or treatment in a study (Creswell, 2014). These activities aim to prepare participants, establish a baseline, and ensure the effectiveness of the intervention (Hofstein & Lunetta, 2004). It is an icebreaker session to establish a positive learning environment and encourage collaboration (Lederman et al., 2014). During this phase, the researcher familiarised participants with the research setting, and equipment available to help reduce anxiety ensuring the students were comfortable with the intervention. This was done to increase participant engagement and motivation (Johnson & Johnson, 2009) and to enhance the validity and reliability of the study's findings (Creswell, 2014). After obtaining consent, the researcher gave the students a pre-test to gauge their readiness and prior understanding. Students were divided into groups based on the findings and availability of resources. After fifty-five (55) minutes of the pre-test, the researcher collected the data, marked, scored and recorded the results. The results were analysis using the students' evaluation scheme in Table 3 and the checklist for assessing students' science process skills. The checklist can be found in Appendix A. These activities were designed to prepare participants, establish a baseline, and ensure the effectiveness of the intervention. To facilitate effective supervision, participation, and meaningful assessment of science process skills during the laboratory practical sessions, the 53 students involved in the study were divided into 13 groups. 12 groups out of the 13 comprised four students each, while the last group had five students. Individual roles within each group were clearly defined to promote collaboration and cooperation throughout the exercises.

Participants underwent a rigorous pre-intervention exercise intended to familiarize them with the research setting and the laboratory equipment, thereby reducing anxiety and ensuring comfort with the intervention process. This step aimed to enhance student engagement and motivation, as well as to increase familiarity with laboratory tools and materials. Students were guided in setting up equipment for a series of physics laboratory experiments. Techniques for accurately reading measurements and avoiding parallax errors were discussed, and participants were given ample time to practice these skills. These preparatory steps were undertaken to ensure students were adequately equipped for the intervention phase. Each group was provided with the necessary equipment and materials. Any challenges encountered were addressed immediately by the researcher. Participants were also introduced to the use of various optical instruments relevant to the selected topics, including ray boxes, spherical mirrors, plane mirrors, lenses, optical pins, meter rules, and both rectangular and triangular glass prisms. These activities allowed students to manipulate the equipment directly, thereby minimizing delays in the development and assessment of science process skills. The data obtained from the pre-intervention exercises were analysed in chapter 4.

3.6.3 Intervention Exercise

Interventions refer to the deliberate actions or strategies implemented to bring about desired changes or improvements in a research study (Creswell, 2014). During this phase, systematic interventions were carried out after the pre-intervention exercises and lasted for four weeks. A total of four practical lessons were conducted during the intervention period, with one lesson carried out each week. A well-prepared lesson plan was used throughout the intervention to ensure consistency, structure, and alignment with the intended learning outcomes. A sample of the lesson plan used during the intervention is presented in Appendix C. The intervention consisted of frequent physics practical activities on some selected topics in optics to improve students' science process skills. Students were put into groups to ensure proper supervision. Students were guided to perform practical experiments on their own. The practical exercises performed in each of the four lessons were constructed and directed toward the specific science process skills to be acquired by the students. Each practical activity lasted for one hundred and ten minutes. Students were assessed on the second lesson of the second day of each week, and their responses to these exercises were collected and marked. The scripts, together with descriptive feedback, were returned to the students before the next lesson. Students' errors and weaknesses were discussed before the new lesson began. The rationale behind these discussions was to enable the participants to become aware of their strengths and areas requiring improvement. The results were analysed using the students' evaluation scheme presented in Table 3 and the checklist for assessing students science process skills. The data obtained from the intervention exercises are presented in Chapter Four.

3.6.4 Post-Intervention Exercise

Post-intervention activities refer to the actions undertaken after the implementation of an intervention to assess its effectiveness, gather feedback, and identify areas for improvement (Creswell, 2014). These activities involved administering post-tests and assessments to measure students' science process skills (SPS) and knowledge retention (Libata et al., 2023). In addition, surveys were conducted to collect students' perceptions and feedback regarding the intervention (Van der Kleij & Lipnevich, 2021). Data obtained from these activities were analysed to determine the effectiveness of the intervention and to identify areas requiring improvement (Hirschfield, 2017).

During this phase of the study, the intervention strategies were evaluated, and their impact on students' development of science process skills was monitored. Students were given a post-intervention task designed to assess their process skills and to determine whether the intervention tool influenced their acquisition of science process skills.

The post-intervention period lasted for two weeks, during which two practical assessments were conducted, one lesson per week. The assessments covered all the science process skills addressed during the intervention phase. Students' responses were assessed based on predetermined expected outcomes. The results from this exercise provided the basis for evaluating both students' performance and the effectiveness of the intervention strategies implemented.

A four-point Likert-scale questionnaire was administered the students to gather data on students' perceptions of how frequent laboratory practical activities contributed to the improvement of their science process skills after the post-intervention activities. The data obtained from the pre-intervention exercises were analysed in chapter 4.

3.6.5 Students' Learning Evaluation Form

This form was designed to gather information on students' performance in the intervention practical activities as well as the post-test. The evaluation form contained specific criteria used to assess students' responses to the assigned tasks during the weekly practical exercises and the post-test activities. The data obtained were used to determine the extent to which students acquired science process skills from the beginning of the study through to the end of the post-intervention stage. Students' responses were carefully analysed to determine whether they met the requirements of the tests. Further details of the students' learning evaluation forms are presented in Table 3.

Table 3: *Students' Learning Evaluation Form*

Degree of acquisition of skills	Criteria for scoring
No acquisition of skills	Blank space or unclear responses
Partial acquisition of skills	Responses that demonstrate some acquisition of science process skills.
Correct acquisition of the necessary skills	Responses that contain all necessary science process skills

3.6.6 Observation Schedule

Observation is a fundamental measuring instruction in physics lab activities, enabling researchers to collect data through systematic and structured procedures (Cai et al. 2021). Observation is a essential data collection method in educational research, allowing investigators to gather first-hand information about students' behaviours, interactions, and learning processes (Cohen et al., 2018). Researchers can learn more about kids' cognitive, social, and emotional development by seeing them in their natural settings (Denzin, 2017). Observation can be used to gather data on various aspects of student behaviour including; Academic engagement; Emotional regulation; Learning strategies; Classroom behaviour; and Teacher-student interactions. (Webb, Nemer, & Chizhik, 2017; Thompson, Cristofalo, & Blevins-Knabe, 2019; Fredricks, Blumenfeld, & Paris, 2019; Johnson et al., 2019; Pintrich et al., 2019; Martin & Bateson, 2019). This is the basic technique of collecting data on the non-verbal bahaviour of participants to collect data based on their behaviour. In this study, the researcher observed the participants in the lab during the practical activities to see how they were responding to the intervention.

3.6.7 Collection of Qualitative Data Instrument

According to Cohen et al. (2018), a Likert scale is a psychometric instrument used to measure attitudes, opinions, or beliefs. In this study, students' qualitative responses were collected using a Likert-type scale with four response categories for each item. The general types of responses included options such as Not Interested, Not Important, Very Important, Never–Often, Strongly Disagree, and Strongly Agree. Among attitudinal scales like the Thurstone, Guttman, and Semantic Differential scales, the Likert-type scale was preferred due to its simplicity and ease of construction. Tittle and Hill (as cited in Page-Bucci, 2003) noted that the Likert scale has been one of the most popular scaling techniques in the social sciences since at least 1967, and it is generally considered more reliable and easier to develop than other attitudinal measures.

Likert scales also allow researchers to calculate frequencies, percentages, and statistical measures such as means and standard deviations (Anderson, 2006), enabling more advanced analyses like Analysis of Variance (Page-Bucci, as cited in Anderson, 2006). Moreover, Likert scales have been found to provide data with relatively high reliability (Robinson, 2024). While some debate exists regarding the suitability of Likert scales for measuring attitudes (Page-Bucci), many researchers, including Robson (as cited in Neuman, 2014), support their use. Respondents often find Likert scales engaging, and Neuman emphasizes their simplicity and practicality.

Likert scales can feature an odd number of points (e.g., 3, 5, 7, or 9) or an even number (e.g., 4, 6, 8, or 10). Odd-numbered scales include a neutral midpoint, but interpreting this middle category can be challenging (Lietz, 2008). To minimize these issues, this study employed a four-point Likert-type scale, omitting the neutral option. One advantage of an even-numbered scale is that it reduces central tendency bias, where respondents may otherwise select the middle option by default (Weijters, Cabooter & Schillewaert, 2010), effectively compelling respondents to indicate agreement or disagreement (Krosnick, Judd & Wittenbrink, 2018).

To maintain objectivity, students were instructed at the start of each question not to select any response if they were unsure. The scale was scored numerically from 1 to 4 (e.g., Not Interested = 1 to Very Interested = 4), with equal intervals between categories assumed to facilitate analysis. This approach allows for judgments regarding relative levels of the measured attribute. The decision to use the Likert scale in this study was supported by its widespread use and acceptance in the research literature.

An interval scale has an origin that is arbitrary with equal-sized intervals between categories. Unlike the interval scale, an ordinal scale, such as a Likert scale does not have equal distances between response categories (Schreiner, 2006). However, it appears it is a common practice in the attitudinal research arena, which assumes equal distances between the categories in the Likert-type scale. In this study, the 4-point

Students were given a Likert scale to measure their opinions and attitudes on the frequent laboratory exercises in physics optics. The purpose of the survey was to evaluate how the intervention affected the students' development of science process abilities. A four-point Likert-type scale was used to examine how students perceived the effect of frequent laboratory practical activities on the acquisition of science process skills. The scale had the following structure: Strongly Disagree is represented by 1, Disagree by 2, Agree by 3, and Strongly Agree by 4. Students' answers were interpreted using the scale's midpoint value, which was determined to be 2.5. The comments of Boone and Boone (2012), who stressed the value of utilizing midpoints in Likert-type scales to evaluate the directional tendency of participants' attitudes, were in line with this interpretative strategy. A mean score of less than 2.5 in this instance denoted general disagreement, meaning that students thought frequent laboratory activities contributed little to nothing to the acquisition of their science process skills. On the other hand, a mean score more than 2.5 denoted agreement, indicating that students thought frequent hands-on activities were important for improving their learning of fundamental scientific concepts. Students who had a score of 2.5 demonstrated a neutral perception, meaning they were neither in agreement nor disagreement with the assertions made.

The quantitative data obtained from the perception survey could be analysed systematically and objectively thanks to this approach. As suggested by Vagias (2006) and confirmed by more current research that highlights the necessity of precisely stated interpretive criteria in Likert-scale research, this approach improved the data' clarity and consistency and supported sound conclusions (Harpe, 2015; Nemoto & Beglar, 2014). Because of their simplicity, dependability, and convenience of use, Likert-type scales remain one of the best instruments in educational research for assessing attitudes, beliefs, and perceptions (Chyung et al., 2018). The application of this scale in the present study enabled the exploration of students' perspectives on how frequent engagement in laboratory activities influenced their mastery of key science process skills. These skills included, but were not limited to, observing, measuring, experimenting, inferring, and communicating. As emphasized by Hofstein and Kind (2012), practical science experiences serve as a vital medium for developing these skills, which are essential for scientific literacy and inquiry-based learning. Therefore, this analytic approach not only quantified students' perceptions but also linked them meaningfully to the broader objectives of science education.

3.7 The Number of Items on the Questionnaire

According to Creswell (2020) questionnaires is a structured instruments used in survey research to collect data from individuals**,** typically in a standardized form that facilitates statistical analysis. In general, a questionnaire can be used for a wide range of research, both quantitative and qualitative, depending entirely on how and where a series of open-ended questions are answered (Sharma, 2022). Sharma went on to say that questionnaires are used when a huge population needs to be evaluated or polled fairly easily because they are essential for learning about the opinions of the people in the population. Creswell (2014). The researcher carefully considered fourteen items when creating the questionnaire for this study in order to gauge how students felt frequent laboratory practicals affected their development of science process abilities in physics optics. The choice of fourteen items is grounded in methodological considerations that ensure validity, reliability, respondent engagement, and efficient data analysis, aligning with best practices in educational research.

Content validity was a key consideration in the selection of these items. Content validity ensures that the questionnaire adequately represents all relevant aspects of the study variables. Given that this study examines students' perceptions of both laboratory practical activities and science process skills, the fourteen items were designed to capture critical dimensions of these experiences. If a questionnaire has too few questions, it may not fully capture students' opinions, but if it includes too many, it can become repetitive and confusing. When deciding on the amount of components, the instrument's internal consistency and dependability were crucial considerations. Cronbach's alpha is frequently used to test reliability, which evaluates whether the items consistently capture the desired construct. Research suggests that a well-balanced number of items improves reliability while minimizing redundancy (Tavakol &

Dennick as cited in Ahmed & Ishtiaq, 2021). A concise yet comprehensive set of ten items ensures that the questionnaire maintains internal consistency and produces dependable data. Additionally, minimizing respondent fatigue and improving response rates played a crucial role in determining the questionnaire length. Since students are the target respondents, it was important to design an instrument that maintains their engagement without causing cognitive overload. Longer questionnaires can lead to participant fatigue, reducing response rates and data accuracy (Ghafourifard, 2024).

By limiting the questionnaire to fourteen well-structured items, the researcher sought to optimize response quality while ensuring that students remain engaged throughout the survey. Research indicates that shorter, focused surveys typically yield better completion rates and more reliable data (Krosnick, 2017). This approach aligns with best practices in educational research. Similar studies assessing students' perceptions of science learning environments have used comparable questionnaire lengths. For instance, Fraser and Walberg (2005) found that structured instruments with approximately ten to fifteen items per domain effectively captured students' views on science education. This precedent reinforces the effectiveness of a fourteen-item questionnaire in providing reliable insights without overburdening respondents.

The selection of fourteen questionnaire items is justified based on principles of content validity, reliability, respondent engagement, and practical data analysis. This number strikes a balance between comprehensiveness and manageability, ensuring that the study gathers meaningful insights into students' perceptions of frequent laboratory practical activities and their role in acquiring science process skills in physics optics.

3.8 Validity of Instrument

According to Trochim (2006), validity describes whether the means of measurement are accurate and whether they are evaluating what they are intended to measure. For the test items to be valid, the items were given to the head of department in physics education and two physics teachers from two neighbouring schools, Begoro Senior High School and Osino Senior High in Begoro and Osino respectively. The validation of the test items was done with the view that it would yield the needed results, which could be used for decision-making and judgment about the acquisition of science process skills by students through the intervention. Cohen, Manion, and Morrison (2017) suggested that using testing as a way of acquiring research data must ensure that it is appropriate, valid, and reliable.

3.9 Reliability

Drost (2011) defined reliability as the consistency or extent to which an instrument measures the same construct each time it is administered to the same individuals under identical conditions. In this study, the reliability of the test instruments was evaluated using a test-retest method. The survey was administered twice to the same group of thirty (30) Form 2 physics students at a nearby school, Osino Presbyterian Senior High, Osino, with a two-week interval between the administrations. The purpose of assessing the instrument’s reliability was to ensure that it would yield consistent and dependable results suitable for informed judgment and decision-making.

The test-retest reliability coefficient was found to be $r = 0.75$, indicating strong consistency and stability of the survey over time. According to Miles and Huberman (as cited in Drucker-Godard, Ehlinger, and Grenier, 2001), a reliability coefficient in the range of 0.60 to 0.65 may still be acceptable if the measurement results are used for making decisions about a group, for research purposes, or when any initial errors can be easily corrected.

3.10 Data Analysis Procedure

The data analysis procedure entails a systematic and transparent process of examining and interpreting the information collected during the study (Creswell, 2014). This process includes checking for errors, addressing missing values, and transforming the data into formats suitable for analysis (Tabachnick, Fidell & Ullman, 2013). It also involves computing descriptive statistics such as means, standard deviations, frequencies, and other summary measures to understand the central tendency and variability of the data (Belotto, 2018), as well as creating plots, charts, and graphs to aid in the visualization and communication of findings (Francis, Jacobsen & Friesen, 2014). In this study, data obtained from the pre-test, intervention tests, and post-test assessing students' science process skills were analysed using appropriate statistical techniques with the support of a statistical software package.

Descriptive statistics, including mean and standard deviation, were calculated for the pre-test, intervention tests, and post-test scores to describe students' performance at each stage of the intervention. These statistics provided an initial insight into changes in students' science process skills over time.

To test the null hypothesis that frequent laboratory practical activities have no significant effect on students' acquisition of science process skills, inferential statistical analysis was conducted. Because the same group of students was assessed at three different points (pre-intervention, during intervention, and post-intervention), a Repeated Measures Analysis of Variance (Repeated Measures ANOVA) was used to determine whether statistically significant differences existed among the mean scores of the pre-test, intervention tests, and post-test.

The level of significance was set at 0.05. The decision criterion was that if the p-value from the repeated measures ANOVA was less than 0.05, the null hypothesis would be rejected, indicating that frequent laboratory practical activities significantly affected students’ acquisition of science process skills. Conversely, if the p-value was greater than or equal to 0.05, the null hypothesis would be accepted.

The results were organized and presented in Chapter Four. For qualitative data, analysis involved describing and interpreting students’ responses and observation reports. Survey data were analysed using SPSS software to simplify interpretation and facilitate clear presentation of the findings.

3.11 Ethical Issues

Ethical issues in research involve ensuring the rights and welfare of participants are protected (American Psychological Association, 2010). The ethical issue involves obtaining participants' consent after providing clear information about the study's purpose, risks, benefits, and rights (Eysenbach & Till, 2001). It addresses the issue of protecting participants' identities and data through anonymization, encryption, or secure storage (Bryman, 2016). Respecting participants' personal information and boundaries (Grady, 2015) is also one of the main issues of concern to be addressed in a study ensuring extra protection for vulnerable groups, such as children, prisoners, or individuals with disabilities (White, 2020). The ethical standards set forth by the school administration were followed in this investigation. All participants gave their informed consent, and the study was conducted with their privacy and confidentiality protected.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

4.0 Overview

This chapter presents and discusses the findings of the study on the effect of frequent laboratory practical activities on students' acquisition of science process skills in physics optics. Specifically, the study aimed to enhance students' science process skills in selected physics topics through regular laboratory practical activities. The chapter begins with a summary of the demographic characteristics of the participants. This is followed by a detailed presentation of the study results, which are organized in line with the research questions and corresponding null hypotheses outlined in Chapter One. Each set of findings is discussed immediately after its presentation to ensure clarity and to relate the results to the broader context of the research.

4.1 Demographic Data of Respondents

The completion rate is a crucial indicator of the reliability and validity of study results. It describes the proportion of participants who finish a study in its entirety (Demerouti & Rispens, 2014). All the 53 student participants in this study completed the research process from beginning to end, yielding a 100% completion rate. Given this high rate, the results are probably representative of the target group, which is Senior High School students

4.2 Pre-Intervention Activities

The participants were taken through pre-intervention exercises to enable the researcher determine students' level of acquisition of skills necessary for practical activities. Students' responses to the demands of the items in the pre-test were analysed and presented as follows:

Task 1: Knowledge about Physical Equipment

Task 1(a): Students were tasked to;

i) identify the laboratory equipment, A, B, C, D and E as seen in Fig.2

ii) explain briefly the functions of the equipment identified in (i)

iii) explain what was observed when light travels through D and E

iv) state the name given to that phenomenon as was observed in (iii)

v) determine the readings on the scales as indicated on equipment A and B

vi) measure and record angle QOP as indicted in F

Task 1(b): Students were tasked to;

i) use their protractor to draw the following angles; 35° , 40° and 50°

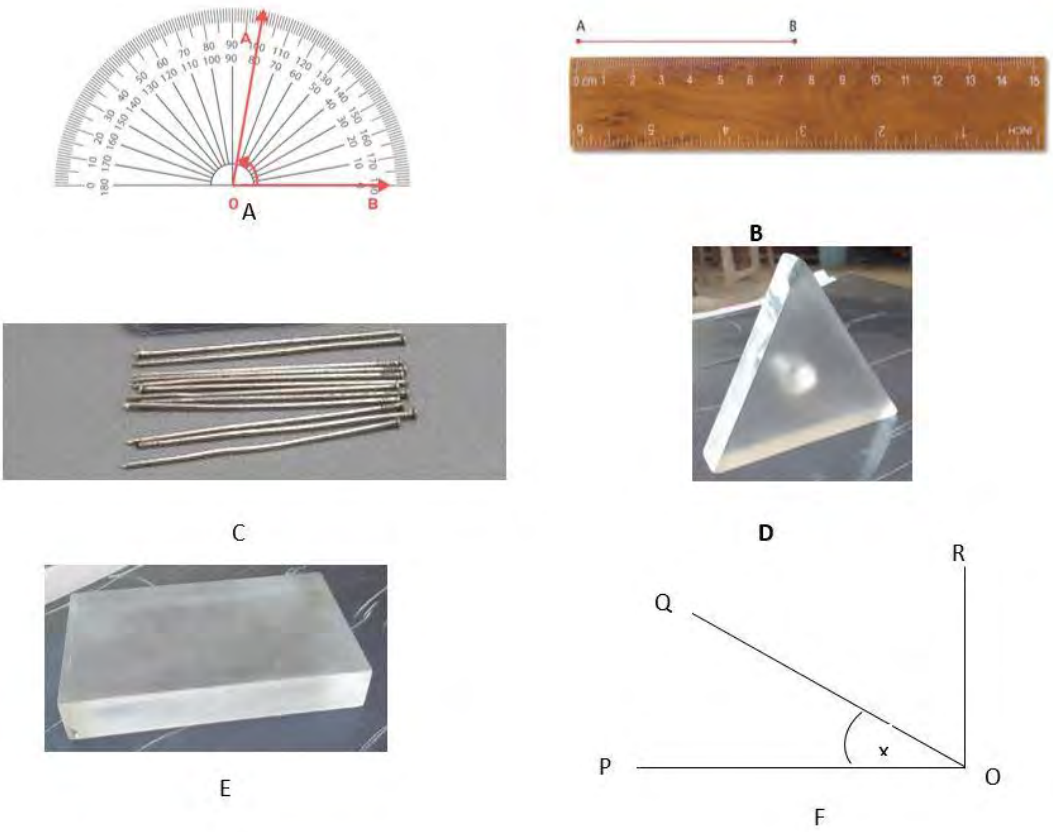


Figure 2: *Equipment to be identified by respondents*

Indicators to identify the required process skills with Task 1 as used in this study

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skill

Experimenting skills constitute the ability of students to plan, design, and carry out experiments to obtain the required data. These skills were measured using a structured evaluation form and an observation checklist where the researcher observed students during laboratory practical activities with the aid of an observation checklist. Indicators for experimenting skills included students' ability to conduct experiments independently without relying continuously on assistance from others, and their ability to use protractors appropriately to measure and record angles accurately..

Measuring Skills

Measuring skills constitute the ability to use scientific instruments to determine physical quantities accurately and precisely. In this study, measuring skills were assessed through direct observation using a structured observation checklist during Task 1**.** The indicators for measuring skills included students' ability to correctly read scales on Equipment A and B, accurately draw angles of 35°, 40°, and 50° using protractors, measure and record the angle QOP as required in Task 1(a)(v), and determine the distance between two indicated points using a metre rule.

Observing Skills

Observing skills constitute the ability of students to carefully notice or detect changes or patterns using the senses or appropriate scientific instruments. In this study, observing skills were assessed through direct observation using a structured observation checklist during Task 1. The indicators for observing skills included students' ability to recognise and correctly identify the equipment provided, as well as observe and describe the change in direction (bending) of light as it passed through a glass prism.

Communicating Skills

Communicating skills constitute the ability of students to express scientific findings clearly through diagrams, tables, graphs, and written or verbal explanations. In this study, communicating skills were assessed through students' written responses and diagrams, supplemented by direct observation using a structured observation checklist during Task 1. The indicators for communicating skills included students' ability to clearly articulate the functions of the identified instruments as required in Task 1(a)(ii), effectively communicate their observations as light passed through a glass prism in Task 1(a)(iii), correctly provide the name of the phenomenon observed when light bends in a prism, and accurately draw the given angle.

Inferring Skills

Inferring skills refer to the ability of students to interpret data or observations in order to make logical conclusions. In this study, inferring skills were assessed through analysis of students' written responses in Task 1, which were subsequently analysed and presented in Table 4. The indicators for inferring skills included students' ability to relate the observed equipment to their known functions and accurately identify the phenomenon observed as light passed through the glass prism.

Table 4: *Analysis of students' Acquisition of Science process Skills for Pre-Intervention Exercise for Task 1*

Science Process Skills	Correct Acquisition of Skills Frequency	Partial Acquisition of Skills Frequency	No Acquisition of Skills Frequency
Experimenting	10(18.87%)	12(22.64%)	31(58.49%)
Measuring	13(24.53%)	11(20.75%)	29(54.72%)
Observing	16(30.19%)	14(26.42%)	23(54.72%)
Communicating	15(28.30%)	10(18.87%)	28(52.83%)
Inferring	8(15.09%)	15(28.30%)	30(56.60%)

Experimenting skill

The data presented in Table 4 indicate that 10 students, representing 18.87% of the respondents, demonstrated correct acquisition of experimenting skills. These students were able to use a protractor independently and accurately measure angle QOP, as required in Task 1(a)(vi), showcasing proficiency in manipulation and handling of experimental tools.

Additionally, 12 students (22.64%) were able to measure the angle QOP accurately; however, they required continuous assistance from their peers throughout the process. Their responses were thus classified as partial acquisition of experimenting skills.

The remaining 31 students, representing 58.49%, were unable to exhibit any meaningful acquisition of experimenting skills. These students struggled to carry out the task independently and were thus categorized as having no acquisition of skills.

Measuring skills

The analysis presented in Table 5 reveals that 13 respondents, representing 24.53%, demonstrated correct acquisition of measuring skills. These students accurately drew the specified angles, 35°, 40°, and 50° using a protractor and correctly measured the angle QOR in Task 1(b)(i), indicating appropriate use of the least count.

Conversely, 11 respondents (20.75%) were able to draw the required angles but failed to measure the angle QOR accurately or indicate the appropriate least count. Their responses were thus classified as partial acquisition of measuring skills. Additionally, a majority of the respondents, 29 students (54.72%), were unable to draw the given angles or measure the angle QOR, and their performance was categorized as no acquisition of measuring skills.

Observing Skill

The analysis presented in Table 5 indicates that the majority of respondents were unable to demonstrate observing skills. Sixteen students, representing 30.19% of the sample, were able to correctly recognize and identify the equipment provided, and they accurately observed and described that light changes direction or bends when it passes through a glass prism. This performance was categorized as correct acquisition of observing skills. Additionally, 14 students (26.42%) recognized and identified the equipment but were unable to accurately observe or describe the bending of light through the prism. Their responses were therefore classified as partial acquisition of observing skills. In contrast, 23 students, accounting for 54.72% of the total, were unable to identify the provided equipment or observe and describe the behaviour of light through the prism. As a result, their performance was categorized as no acquisition of observing skills.

Communicating Skill

Data from Table 5 show that 15 students, representing 28.30% of the respondents, successfully demonstrated the acquisition of communicating skills. These students were able to clearly articulate the functions of the identified instruments and effectively communicate their observations regarding the behaviour of light as it passed through the glass prism.

Additionally, 10 students (18.87%) were able to express their findings to a reasonable degree; however, some inaccuracies in their descriptions led to their responses being classified as partial acquisition of communicating skills.

In contrast, 28 students (52.83%) were unable to effectively communicate their findings. They struggled to explain their observations and interpretations, and as a result, their responses were categorized as no acquisition of communicating skills.

Inferring Skills

In the task, respondents were required to predict what happens to light as it moves from one medium to another and to identify the name of the phenomenon associated with this behaviour. Out of the 53 respondents, 9 students (16.98%) accurately predicted that light changes direction when transitioning between media and correctly identified the phenomenon as *refraction*. This performance was classified as correct acquisition of inferring skills. Additionally, 15 students (28.30%) were able to predict the behaviour of light but failed to provide the correct name of the phenomenon. Their responses were therefore classified as partial acquisition of inferring skills. Conversely, 30 students (56.60%), the majority did not demonstrate any meaningful understanding of the phenomenon. They were unable to draw logical conclusions from the information provided, and as a result, their responses were categorized as no acquisition of predicting skills.

4.2 Intervention Results

To examine the effect of frequent laboratory practical activities on students’ acquisition of science process skills in selected topics in optics, participants engaged in four weeks of instruction using practical-based activities. At the end of each week, students completed assessment tasks designed to measure the science process skills developed during that week and the preceding one. Test results were returned to students before the subsequent lesson to allow time for remediation in areas of weak performance.

Targeted feedback was provided through written comments on incorrect responses, enabling students to identify and correct their errors in subsequent activities. These feedback sessions were discussed with students to enhance their understanding of the mistakes made and the expected responses. This approach supported the progressive development of science process skills throughout the intervention period.

Students’ responses were analysed using descriptive statistical tools, including tables and charts, to address three research questions and one hypothesis. The practical activities focused on optics topics previously covered in class but identified by the researcher as areas where students demonstrated inadequate science process skills. Assessment was conducted at the end of each lesson based on the specific science process skills targeted for that week, and the resulting data were analysed and presented in the results section using appropriate descriptive statistics.

4.2.1 Week 1-Lesson One

Each lesson began with a review of students' prior knowledge, during which any challenges previously encountered by the participants were addressed. The day's activity was then introduced to the students within their respective groups, as outlined in the assigned tasks. Students were guided through essential safety and procedural precautions relevant to each practical activity. These included avoiding parallax error when tracing images and accurately reading measurements from instruments such as protractors and metre rules. Additional procedures involved cleaning the surfaces of optical equipment, including rectangular glass prisms, lenses, and mirrors, to ensure accurate results. Following these preparatory steps, students responded to practical questions based on the completed activities. Their responses were analysed and are presented in Table 5.

Task 2: Knowledge about the Behaviour of Light Through Medium

Students were provided with rectangular glass block, drawing board, drawing paper, optical and thumb pins to perform the following activities as well as the diagram in Fig 3 to aid them.

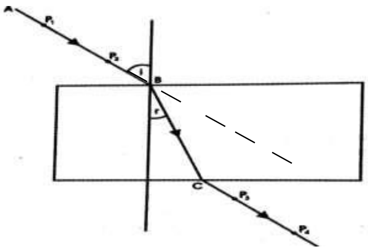


Figure 3: *Illustration of Refraction of Light through a Rectangular Glass Prism*

Respondents were tasked to:

i) place the rectangular glass prism with one of its broad faces on the sheet of drawing paper provided. Trace its outline.

ii) choose a point **B** near the centre of one of the longer sides of the outline and draw a perpendicular to that side of the outline through it.

iii) draw a line **AB** making an angle of incidence **i = 20**° with the perpendicular at **B**. Replace the block on its outline. Fix two pins at **P1** and **P2**. Fix two other pins at **P3** and **P4** such that the pins appear to be on a straight line with the images of **P1** and **P2** when viewed from the opposite side. Remove the rectangular glass prism and draw a line through **P3** and **P4** to meet the outline at **C**. Join **B** to **C**.

iv) measure and record the angle of refraction ***r***, hence determine the angle of deviation, d. Repeat the procedure for *i* = 30°, 40°, 50°, and 60°. In each, determine the value of r.

v) explain your observation as the angle of incidence is increased and its effects on angle of refraction and the emergent ray.

Their responses were presented and analysed in Table 5.

Indicators to identify the required science process skills with Task 2 as used in this study

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skills

These skills involved planning and executing a controlled procedure, manipulating variables, and systematically collecting data. In this study, experimenting skills in Task 1 were assessed through direct observation using a structured observation checklist and evaluation form during the practical activity. The indicators for experimenting skills included students' ability to identify limitations and sources of error when conducting the experiment, select appropriate materials for the laboratory activity, correctly set up the glass block and pins according to the given instructions, trace the block accurately, draw lines at specified angles, and repeat the procedure for different angles of incidence.

Measuring skills

Measuring skills involve the ability to use scientific instruments to make accurate and precise measurements. In Task 1, measuring skills were assessed using both a structured observation checklist and an evaluation form. The indicators included students' ability to accurately measure the angles of incidence, refraction, and deviation, and to record precise numerical values using the appropriate tools or instruments.

Observing skills

The indicators for the acquisition of observing skills in Task 1 included identifying a suitable light source that provides clear images and ensuring that parallax error was avoided. Respondents were expected to visually align pins P3 and P4 with the images of pins P1 and P2 through the glass prism. Additionally, they were required to observe how the light ray bends as it passes through the glass, noting the occurrence of refraction at both the air-glass and glass-air boundaries. Detecting small variations in ray positions as the angle of incidence changed also constituted a key indicator of observing skills. In this study, observing skills were assessed using both a structured observation checklist and an evaluation form**.** These assessment methods captured students' ability to perform the above actions accurately, reflecting the correct acquisition of observing skills in Task 1.

Communicating skills

The indicators for communicating skills in Task 1 included drawing clear and accurate ray diagrams on paper, labelling points, angles, and ray paths, and tabulating values of the angle of incidence (i), angle of refraction (r), and distance (d) neatly, with the appropriate least count. Respondents were also expected to articulate the procedure used to trace the image of the optical pins in the glass prism, clearly label all points in their diagrams as required by the task, and explain their observations regarding the effect of increasing the angle of incidence on the angle of refraction and emergent rays as light passed from air into the glass prism. In this study, communicating skills were assessed using both a structured observation checklist and an evaluation form**,** which captured students' ability to perform the above actions accurately, thereby reflecting the correct acquisition of communicating skills in Task 1

Inferring skills

The indicators for inferring skills in Task 1 included concluding how the angles of deviation change with the angle of incidence, understanding that light bends due to a change in medium, drawing scientific conclusions from trends in the recorded data, inferring that light travels more slowly in glass than in air, and explaining the bending using the concept of optical density. In this study, inferring skills were assessed using both a structured observation checklist and an evaluation form**,** which captured students' ability to interpret their observations and draw logical conclusions based on the experimental results.

Table 5: *Analysis of Students' Responses to Task 1 of the Intervention Exercises*

Science Process Skills	Correct Acquisition of Skills Frequency	Partial Acquisition of Skills Frequency	No Acquisition of Skills Frequency
Experimenting	15(28.30%)	13(24.53%)	25(47.17%)
Measuring	19(35.85%)	12(22.68%)	21(39.62%)
Observing	24(45.28%)	13(24.53%)	16(30.19%)
Communicating	18(33.96%)	15(28.30%)	20(37.74%)
Inferring	12(22.64%)	18(35.85%)	23(43.40%)

Experimenting Skill

The analyses presented in Table 5 indicate an improvement in the acquisition of experimenting skills compared to previous activities. Fifteen students (28.30%) demonstrated correct acquisition of experimenting skills. These students were able to identify limitations and sources of error during the experiment. They successfully identified and selected appropriate materials for the experiment, set up the glass block and pins as instructed, traced the block, drew lines at specific angles, and repeated the procedure for various angles of incidence. They also demonstrated their manipulation skills by accurately tracing the image as expected. Furthermore, they repeated the experiment to verify results and increase reliability, which constituted correct acquisition of experimenting skills.

Thirteen students (24.53%) were able to maintain a safe and controlled experimental environment and comport themselves appropriately within their groups. They also successfully identified and selected appropriate materials for the experiment. However, they struggled to trace the image correctly, which led to a classification of partial acquisition of experimenting skills.

In contrast, 25 students (47.17%) did not exhibit any meaningful acquisition of experimenting skills. They were unable to carry out the necessary steps of the experiment effectively, and their responses were therefore classified as no acquisition of skills.

Measuring Skill

The analysis presented in Table 5 reveals an improvement in students' acquisition of measuring skills. According to the data, 19 respondents (35.85%) demonstrated correct acquisition of measuring skills. These students were able to trace the outline of the rectangular prism, accurately draw the normal line and angle of incidence using their protractors, and measure the angle of refraction correctly, ensuring the appropriate least count was indicated.

In contrast, 12 respondents (22.68%) were able to trace the outline, draw the normal line, and the angle of incidence correctly. However, they struggled to measure the angle of refraction accurately and did not obtain the expected values. As a result, their responses were classified as partial acquisition of measuring skills.

Additionally, 21 respondents (39.62%) were unable to demonstrate any meaningful acquisition of measuring skills. These students were unable to draw the normal line, angle of incidence, or angle of refraction. Consequently, their responses were classified as no acquisition of measuring skills.

Observing Skills

The analysis presented in Table 5 shows an improvement in the number of respondents who acquired observing skills compared to previous data. Of the respondents, 24 (45.28%) demonstrated correct acquisition of observing skills. These participants were able to trace the image of the optical pins with ease and identify a light source that provided clear images. They also ensured that the error of parallax was avoided and were able to observe the relationship between the angle of incidence and angle of refraction. Moreover, they noted that as the angle of incidence increased, the emergent rays moved toward the normal. This group's responses were classified as correct acquisition of observing skills.

In contrast, 13 respondents (24.53%) were able to trace the optical pins' images clearly in the glass prism and avoid parallax errors. They also identified the correct light source. However, these participants struggled to establish a clear relationship between the angle of incidence and angle of refraction based on their observations. Therefore, their responses were classified as partial acquisition of observing skills.

Additionally, 16 respondents (30.19%) were unable to trace the images of the optical pins properly due to parallax errors. They also failed to establish any meaningful relationship between the angle of incidence and angle of refraction. Consequently, their responses were classified as no acquisition of observing skills.

Communicating Skills

Data from Table 5 show that 18 students, representing 33.96%, were able to communicate their findings correctly. These respondents were able to clearly articulate the procedure used in tracing the image of the optical pins in the glass prism. They also accurately labelled their diagrams, showing all points as required by the question. Furthermore, they were able to explain their observations regarding the effect of increasing the angle of incidence on the angle of refraction as light moved from air into the glass prism. Additionally, they understood and explained that as the angle of incidence increased, the emergent rays moved toward the normal. These students demonstrated correct acquisition of communicating skills.

On the other hand, 15 students (28.30%) were able to label their diagrams clearly and communicate their findings well. However, they struggled with explaining the procedure used to obtain the results, which resulted in partial acquisition of communicating skills.

20 students (37.74%) were unable to articulate their findings effectively or demonstrate that they had acquired the necessary skills. They struggled to explain the procedure used in the experiment, leading to their responses being classified as no acquisition of skills

Inferring Skills

Respondents were expected to observe and recognize the relationship between the angle of incidence and the angle of refraction, particularly how changes in one influence the other. Additionally, they were required to demonstrate an understanding of how the refractive indices of the media affect the bending of light and why the angle of refraction differs from the angle of incidence.

Out of 53 respondents, 12 (22.64%) demonstrated correct acquisition of predicting skills. These respondents were able to observe and recognize the relationship between the angle of incidence and the angle of refraction, accurately identifying how changes in one influence the other. They also displayed an understanding of how the refractive indices of different media affect the bending of light and why the angle of refraction differs from the angle of incidence.

18 students (35.85%) exhibited partial acquisition of inferring skills. While they were able to observe and recognize the relationship between the angle of incidence and the angle of refraction, they were unable to demonstrate an understanding of how the refractive indices of the media affect the bending of light or explain why the angle of refraction differs from the angle of incidence.

The remaining 23 students (43.40%), the majority of respondents, showed no acquisition of inferring skills. These students were unable to observe or recognize the relationship between the angle of incidence and the angle of refraction. They also struggled to demonstrate an understanding of how the refractive indices of media affect light bending or explain why the angle of refraction differs from the angle of incidence.

4.2.3 Week 2-Lesson Two

The lesson started with revision of students' previous knowledge. Few challenges encountered by the participants were addressed. The exercise for the day was introduced to them in their various groups as shown below. This exercise was similar to that of week one activity 2. However, participants were tasked to perform additional activities such as evaluating ***sin i*** and ***sin r***.

Task 3: Knowledge about the Behaviour of light through glass block

Students were provided with rectangular glass block, drawing board, drawing paper, optical and thumb pins to perform the following activities as well as the diagram in Fig 4 to aid them.

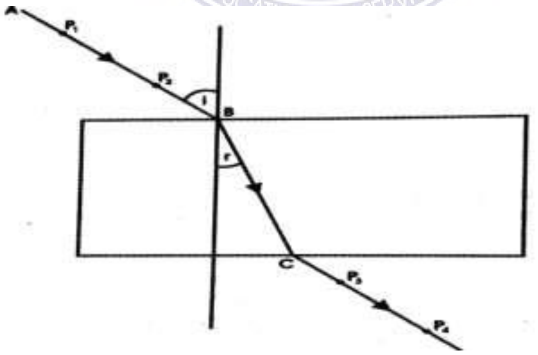


Figure 4: *Illustration of Refraction of Light through a Rectangular Glass Prism*

Students were tasked to:

i) place the rectangular glass prism with one of its broad faces on the sheet of drawing paper provided. Trace its outline.

ii) choose a point **B** near the centre of one of the longer sides of the outline and draw a perpendicular to that side of the outline through it.

iii) draw a line **PO** making an angle of incidence **i = 30°** with the perpendicular at **B**. Replace the block on its outline. Fix two pins at **P1** and **P2**. Fix two other pins at **P3** and **P4** such that the pins appear to be on a straight line with the images of **P1** and **P2** when viewed from the opposite side.

iv) remove the rectangular glass prism and draw a line through **P3** and **P4** to meet the outline at **C**. Join **B** to **C**

v) measure and record the angle of refraction ***r***. evaluate ***sin i*** and ***sin r***.

vi) repeat the procedure for ***i*** = *35°*,, *40°*, *45°*, *and 50°*,. In each case, evaluate ***sin i*** and ***sin r***.

vii) tabulate their readings.

Their responses were analysed and presented in Table 6.

Indicators to identify the required science process skills with Task 2 as used in this study.

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skills

The indicators for experimenting skills in Task 2 included identifying limitations and sources of error during the light experiment, selecting and using appropriate materials for the laboratory activity, and following step-by-step instructions. Respondents were expected to correctly set up the apparatus, carefully place the glass block on its outline, trace the outline, and position the pins vertically with precision. They were also required to set the incident angles, place the pins, and repeat the procedure as necessary. Additionally, students were expected to ensure safety and maintain neatness throughout the experiment. In this study, experimenting skills were assessed using both a structured observation checklist and an evaluation form**,** which captured students' ability to plan, execute, and complete the experiment accurately and systematically.

Measuring skills

The indicators for measuring skills in Task 2 included using a protractor to measure the angles of incidence (i) and refraction (r) accurately. Respondents were expected to measure each angle carefully from the correct baseline to avoid parallax errors, record each angle in degrees along with the corresponding sine values without skipping steps, and present the values clearly in a well-organized Table 6. In this study, measuring skills were assessed using both a structured observation checklist and an evaluation form, which captured students' ability to obtain precise and accurate measurements during the experiment.

Observing skills

In exhibiting this skill, the indicators include carefully aligning the pins to trace the true path of the refracted ray, observing how the light ray bends inside the glass block as the angle of incidence increases, and noticing how the refraction behaviour changes with varying angles. Additionally, students should be able to identify variations in the angle of refraction as the angle of incidence changes, while ensuring precision and consistency in recording their data

Communicating skills

The indicators for communicating skills in Task 2 include drawing and labelling ray diagrams, showing both incident and refracted rays. They also involve tabulating readings for each angle, including values for i, r, sin i, and sin r. Additionally, presenting the data in a scientific format in preparation for graph plotting is an essential component. These activities collectively constitute the communication skills required for the task.

Inferring skills

Inferring skills involve the ability to draw logical conclusions based on data, patterns, or observed relationships. In Task 2, the indicators for inferring skills include respondents identifying a near-linear relationship between the angles of incidence and refraction. They demonstrated evidence of Snell's law and observed that as the angle of incidence increases, the angle of refraction also increases. Respondents also compared the values of sin i and sin r to identify the proportional relationship between the two. Additionally, they used the values obtained to explain how light bends when entering a denser medium from air. These skills also involved connecting the experimental results to theoretical concepts taught during the lecture, thereby reinforcing the link between the practical experiment and the theoretical principles of optics.

Table 6: *Analysis of Students' Responses to Task 2 of the Intervention Exercises*

Science Process Skills	Correct Acquisition of Skills Frequency	Partial Acquisition of Skills Frequency	No Acquisition of Skills Frequency
Experimenting	19(35.85%)	15(28.30%)	19(35.85%)
Measuring	21(39.62%)	14(26.42%)	18(33.96%)
Observing	29(54.72%)	16(30.19%)	8(15.09%)
Communicating	23(43.40%)	17(32.08%)	13(24.53%)
Inferring	18(33.96%)	15(28.30%)	20(37.74%)

Experimenting Skills

The analysis presented in Table 6 reveals that 19 students, representing 35.85%, were able to fully exhibit experimenting skills. These students demonstrated the ability to identify potential limitations and sources of error during the light experiment. They were also able to select and arrange appropriate materials for the experiment, ensuring the glass block was aligned correctly. They carefully traced the path of the incident and refracted rays, and they systematically documented their observations, presenting the data in a clear and organized table that included angles of incidence and refraction with the correct least count. This constitutes the correct acquisition of experimenting skills. On the other hand, 15 students (28.30%) exhibited partial acquisition of experimenting skills. They struggled to document their observations in a systematic manner, often failing to include accurate details such as the least count in their tables showing angles of incidence and refraction. They frequently relied on peers for assistance and guidance during the process.

Lastly, 19 students (35.85%) demonstrated no meaningful acquisition of experimenting skills. These students consistently required guidance from the instructor and were unable to perform the experiment independently. They struggled to follow the procedure correctly and failed to document their findings properly, resulting in their responses being classified as no acquisition of experimenting skills.

Measuring Skills

The analysis presented in Table 6 revealed an improvement in students' acquisition of measuring skills. According to the data, 29 respondents, representing 54.72%, demonstrated correct acquisition of measuring skills. These students were able to align the protractor's baseline accurately with the normal line to ensure precise angle measurements. Their ability to follow proper measurement procedures and maintain consistency in recording results reflects a strong understanding of the task and constitutes correct acquisition of the skill.

In contrast, 16 students (30.19%) demonstrated partial acquisition of measuring skills. While they were able to trace the outline, draw the normal, and accurately indicate the angle of incidence provided, they encountered several challenges. Their tables of values included omissions, and they frequently relied on peers for clarification and support. These gaps in independence and accuracy limited their demonstration of full competence. Meanwhile, 8 students (15.09%) were unable to exhibit meaningful acquisition of measuring skills. They struggled to align the protractor’s baseline with the normal line and were unable to take precise angular measurements. As a result, their responses were classified as demonstrating no acquisition of the skill.

Observing Skills

The analysis presented in Table 6 indicates an improvement in the number of respondents who acquired observing skills compared to previous data. A total of 21 students, representing 39.62%, demonstrated correct acquisition of observing skills. These students consistently followed all steps involved in the experiment and paid close attention to detail. They accurately identified variations in the angle of refraction as the angle of incidence changed and maintained precision and consistency in recording their data. They ensured proper alignment of optical pins and images, recognized external factors, such as alignment errors, that could affect observations, and were able to trace the image of the optical pins without difficulty. Furthermore, they selected appropriate light sources to produce clear images and actively worked to avoid parallax errors. These practices reflect a strong acquisition of observing skills.

Meanwhile, 14 respondents (26.42%) demonstrated partial acquisition of observing skills. They were able to trace the images of the optical pins clearly and set up the optical components, but often struggled to achieve precise alignment, which affected the accuracy of their observations. These students frequently required guidance to identify and correct misalignments or improper placements within the experimental setup. Although they recognized changes in the light path, they had difficulty identifying smaller deviations caused by experimental error. Their performance indicated potential for skill mastery but a need for additional support, focus, and conceptual understanding. Conversely, 18 respondents (33.96%) did not demonstrate meaningful acquisition of observing skills. They were unable to align the optical equipment independently and relied heavily on others for conducting the experiment and collecting data. Despite repeated exposure, demonstrations, and instructional support, they showed no significant improvement. These students exhibited a lack of basic understanding and confidence in executing the assigned tasks, resulting in their classification as having no acquisition of observing skills

Communicating Skills

Data from Table 6 show that 23 respondents, representing 43.40%, fully demonstrated the acquisition of communicating skills. These students were able to draw and accurately label ray diagrams showing both incident and refracted rays. They correctly tabulated their readings for each angle, including values for *i*, *r*, sin *i*, and sin *r*, and presented their data in a clear, scientific format suitable for graph plotting. These abilities reflect a complete and accurate acquisition of communicating skills in Task 3. In contrast, 17 participants (32.08%) demonstrated partial acquisition of communicating skills. While they were able to engage with the task, they often relied on peers or the instructor for clarification and support. Although they showed a basic understanding of the required concepts, they struggled to express deeper insights independently. Their data tables contained omissions or inconsistencies, which limited the clarity and completeness of their communication. Meanwhile, 13 students (24.53%) did not demonstrate meaningful acquisition of communicating skills. Their explanations were inaccurate or unclear, and they were unable to articulate their observations effectively. The information they provided was often disorganized and incoherent, leading to their classification as having no acquisition of the skill.

Inferring Skill

The data presented in Table 6 show that 18 respondents, representing 33.96%, fully demonstrated the acquisition of inferring skills. These students were able to analyse, interpret, and explain their experimental results effectively, reflecting a strong understanding of optical principles. Their responses showed evidence of applying Snell's Law, as they successfully compared values of sin *i* and sin *r* to identify the proportional relationship between them. They used their data to explain how light bends when transitioning from air into a denser medium and were able to relate their findings to theoretical concepts covered during instruction. This level of interpretation indicates a correct acquisition of inferring skills. Conversely, 15 respondents (28.30%) demonstrated partial acquisition of inferring skills. While they showed some ability to interpret their experimental results and recognize patterns and trends, they struggled with consistency and depth of understanding. These students required support to fully explain and justify their conclusions, indicating developing but incomplete mastery of inferring skills. Meanwhile, 20 respondents (37.74%) did not demonstrate meaningful acquisition of inferring skills. They were unable to draw logical conclusions from their data and exhibited difficulty interpreting the relationships observed during the experiment. As a result, their responses were classified as no acquisition of inferring skills

4.2.4 Week 3-Lesson Three

Task 4: Knowledge about the behaviour of light through glass block

Students were provided with rectangular glass block, drawing board, drawing paper, optical and thumb pins to perform the following activities as well as the diagram in Fig 5 to aid them.

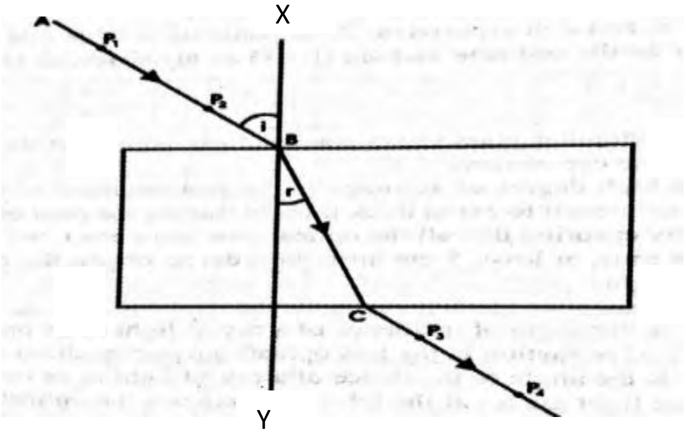


Figure 5: *Illustration of Refraction of Light through a Rectangular Glass Prism*

Students were tasked to:

i) choose a point **B** near the centre of one of the longer sides of the outline and draw a perpendicular to that side of the outline through it.

ii) draw a line **AB** making an angle of incidence **i = 20°** with the perpendicular at **B**. Replace the block on its outline. Fix two pins at $\mathbf{P_1}$ and $\mathbf{P_2}$. Fix two other pins at $\mathbf{P_3}$ and $\mathbf{P_4}$ such that the pins appear to be on a straight line with the images of $\mathbf{P_1}$ and $\mathbf{P_2}$ when viewed from the opposite side.

iii) remove the rectangular glass prism and draw a line through $\mathbf{P_3}$ and $\mathbf{P_4}$ to meet the outline at **C**. Join **B** to **C**.

iv) measure and record the angle of refraction ***r***. Repeat the procedure for four other values of **i**.= 30°, 40°, 50° and 60°. In each case, determine the corresponding values of ***r***.

v) tabulate the readings.

vi) plot a graph with sin i as the ordinate and ***sin r*** as the abscissa.

vii) Determine the slope ***s*** of the graph.

viii) State the significance of the slope

ix) State two precautions you took in performing this experiment

Indicators to identify the required science process skills with Task 3 as used in this study

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skills

The indicators of experimenting skill in Task 3 includes following step-step instructions, setting up apparatus correctly, carefully placing the glass block on its outline, tracing the outline of the glass block, controlling errors by carefully positioning the pins vertically and align them with precision, setting incident angles, placing pins and repeating the procedure. The indicators includes correctly drawing of axes and labelling them and plotting of the values obtained and demonstrating the concept of a line of best fit and its significance. It also includes, ensuring safety and neatness and repeating the experiment multiple times for reliability

Measuring skills

The indicators for measuring skills for Task 3 includes respondents using protractor to measure angle of incidence(i) and angle of refraction(r) accurately, measuring each angle carefully from the correct baseline to avoid parallax errors, writing down each angle in degree and sine values without skipping steps, creating a neat, organised tables for all measured and computed values. These constitute measuring skills.

Observing skills

In demonstrating this skill, the indicators include the respondent's ability to identify a light source that provides clear images and to take steps to avoid parallax error. Observing skills also involve carefully monitoring the alignment of optical pins through the glass and detecting when pins P3 and P4 visually align with the images of P1 and P2. Additionally, students are expected to notice how the light ray bends within the glass block as the angle of incidence (*i*) increases. Other indicators include maintaining precision and consistency in data recording and recognizing that an increase in the angle of incidence results in an increase in the angle of refraction, though at a decreasing rate. These actions collectively represent the proper acquisition of observing skills.

Communicating skills

The indicators of communicating skills in Task 3 include the ability to draw and label ray diagrams clearly, showing both incident and refracted rays. Students were expected to tabulate their readings for each angle, displaying values for *i* and *r*, and accurately calculate sin *i* and sin *r* using a calculator. Effective communication also involved presenting the data in a scientific format in preparation for graph plotting. This included correctly labelling the axes with appropriate units and scales, plotting the obtained values, determining the slope of the graph, and articulating the significance of that slope. These components collectively represent the expected demonstration of communicating skills in the given task.

Inferring skills

Inferring skills involve the ability to draw logical conclusions based on data, patterns, or observed relationships. In Task 3, the indicators of inferring skills included the analysis of the relationship between sin *i* and sin *r*, recognizing that the slope of the graph represents the refractive index, and concluding that light bends toward the normal when it passes from air into glass. These actions reflect a deeper understanding of the underlying physical principles and demonstrate the ability to interpret experimental data meaningfully.

Table 7: *Analysis of Students' Responses to Task 3 of the Intervention Exercises for week 3*

Science Process Skills	**Correct Acquisition of Skills** Frequency	**Partial Acquisition of Skills** Frequency	**No Acquisition of Skills** Frequency
Experimenting	23(43.40%)	17(32.08%)	13(24.53%)
Measuring	34(64.15%)	13(24.53%)	6(11.32%)
Observing	38(71.70%)	10(18.87%)	5(9.43%)
Communicating	30(56.60%)	17(32.08%)	6(11.32%)
Inferring	24(45.28%)	18(33.96%)	11(20.75%)

Experimenting Skill

Data presented in Table 7 indicate that 23 students, representing 43.40% of the respondents, demonstrated correct acquisition of experimenting skills. These students successfully arranged the apparatus to ensure accurate measurements, including proper alignment of the glass block. They carefully traced the paths of the incident and refracted rays and systematically documented their observations in a table showing angles of incidence and refraction. Additionally, they correctly drew and labelled the axes, plotted the recorded points, and accurately demonstrated the concept and significance of a line of best fit. These competencies reflect a solid acquisition of experimenting skills.

In contrast, 17 students (32.08%) demonstrated partial acquisition of experimenting skills. While they exhibited a basic understanding of the relationship between the angle of incidence and the angle of refraction, and documented their observations in a structured table, they encountered challenges when plotting the data points. Although they were able to draw the axes correctly, their difficulty in accurately plotting the results affected the overall interpretation of the experiment. Meanwhile, 13 students

(24.53%) did not demonstrate meaningful acquisition of experimenting skills. These students were unable to perform the task independently and frequently relied on the instructor for guidance. Their responses lacked the necessary components of experimental design, data recording, and graphical analysis, resulting in their classification as having no acquisition of the skill.

Measuring Skill

From the data presented in Table 7, 34 respondents, representing 64.15%, demonstrated correct acquisition of measuring skills. These students were able to align the protractor's baseline with the normal line to ensure precise angle measurements and maintained consistency in recording their values. They were also able to identify potential sources of error in their measurements and organized their data in a clear, logical manner, using appropriate units and notation. These abilities constitute the correct acquisition of measuring skills.

In contrast, 13 respondents (24.53%) demonstrated partial acquisition of measuring skills. These students were able to trace the outline, draw the normal, and correctly mark the angle of incidence provided to them. However, they faced some challenges. Although they measured angles accurately most of the time, they occasionally made errors and omissions. While they showed consistency in their recordings, issues with accuracy limited their performance, resulting in classification as partial acquisition. Meanwhile, 6 students (11.32%) did not demonstrate meaningful acquisition of measuring skills. They were unable to align the protractor's baseline with the normal line, which affected the accuracy of their measurements. Additionally, they struggled to interpret the protractor scale correctly to record angles in degrees and failed to maintain consistency in their data recordings. Consequently, their responses were classified as no acquisition of measuring skills.

Observing Skill

The analysis presented in Table 7 indicates that most participants acquired observing skills more successfully than other science process skills. A total of 38 respondents, representing 71.70%, demonstrated correct acquisition of observing skills. They followed all steps of the experiment carefully, identified appropriate light sources that provided clear images, and avoided parallax errors. They maintained proper alignment of the optical pins and image by ensuring that P3 and P4 were visually aligned with the images of P1 and P2. Their data recording was precise and consistent. Additionally, they observed that an increase in the angle of incidence led to a corresponding increase in the angle of refraction, though at a decreasing rate. On the other hand, 10 respondents (18.87%) demonstrated partial acquisition of observing skills. They were able to trace the images of the optical pins clearly and set up the optical components, but often failed to achieve precise alignment. They required guidance to correct misalignments and improper placements in the setup. Although they recognized changes in the light path, they struggled to detect small deviations caused by experimental errors. These students showed potential but required further support to improve focus, accuracy, and understanding.

Meanwhile, 5 respondents (9.43%) did not demonstrate meaningful acquisition of observing skills. They relied entirely on others for data collection, showed no improvement despite repeated instruction and demonstrations, and lacked basic understanding and confidence in performing the assigned tasks. As such, their responses were classified as no acquisition of the skill.

Communicating skill

The number of students exhibiting the acquisition of this skill was relatively low compared to other skills, except for inferring skills. Data presented in Table 7 show that

30 students, representing 56.60%, fully demonstrated the acquisition of communicating skills. These students presented their findings in a well-structured and coherent manner. They were able to draw and label ray diagrams clearly, showing both incident and refracted rays. Their data was tabulated accurately, displaying values for *i*, *r*, sin *i*, and sin *r* for each measured angle. They presented their data in a scientific format appropriate for graph plotting, correctly labelled the axes with appropriate units and scales, plotted the values obtained, and accurately calculated the slope of the graph. Furthermore, they correctly stated the significance of the slope. These actions constitute the correct acquisition of communicating skills.

On the other hand, 17 students, representing 32.08%, demonstrated only partial acquisition of communicating skills. While they also presented their findings in a well-structured manner, drew and labelled ray diagrams, and tabulated readings for *i*, *r*, sin *i*, and sin *r*, they often relied on their peers or the instructor for guidance in clarifying ideas. Although they correctly prepared the data for graph plotting and labelled the axes appropriately, they faced challenges in plotting the values accurately. These difficulties affected the accuracy of their line of best fit and slope, resulting in their responses being classified as partial acquisition.

Meanwhile, 6 students (11.32%) failed to demonstrate meaningful acquisition of communicating skills. They were unable to articulate their observations during the experiment and presented information in a disorganized and incoherent manner. Consequently, their responses were classified as showing no acquisition of communicating skills.

Inferring Skill

The data presented in Table 7 show that 24 respondents, representing 45.28%, fully demonstrated the acquisition of inferring skills. These students were able to analyse the relationship between sin *i* and sin *r*, and correctly recognized that the slope of the graph represents the refractive index of the glass. They also accurately inferred that light bends toward the normal when moving from air into glass. These abilities constitute the correct acquisition of inferring skills.

On the other hand, 18 participants, representing 33.96%, demonstrated partial acquisition of inferring skills. While they were able to analyse the relationship between sin *i* and sin *r*, and correctly inferred that light bends toward the normal when transitioning from air into glass, they failed to recognize that the slope of the graph corresponds to the refractive index. This limitation resulted in their responses being classified as partial acquisition. Meanwhile, 11 respondents (20.75%) did not demonstrate any meaningful acquisition of inferring skills. They struggled to draw valid conclusions from the data and were unable to interpret the graph or identify key relationships. As a result, their responses were classified as showing no acquisition of inferring skills.

4.2.5 Week 4- Lesson Four

Task 5: Knowledge about the behaviour of light through triangular glass block

Students were provided with rectangular glass block, drawing board, drawing paper, optical and thumb pins to perform the following activities as well as the diagram in Fig 6 to aid them.

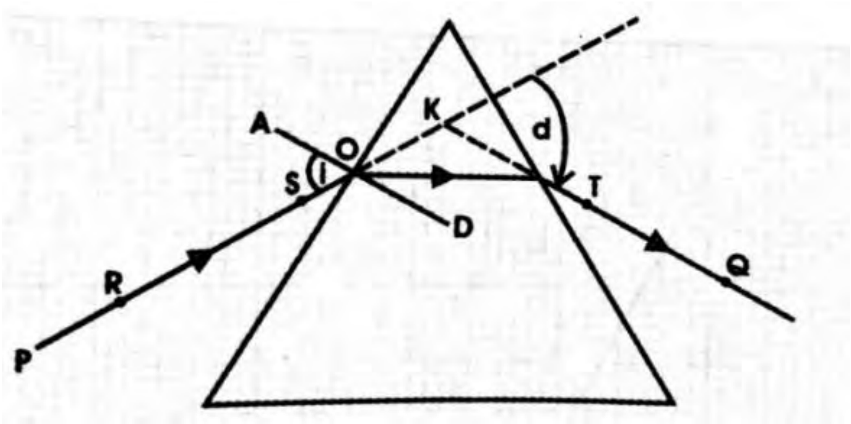


Figure 6: *Illustration of Refraction of Light through a Triangular Glass Prism*

Students were tasked to:

i) Trace the outline of the given triangular glass prism on the sheet of paper provided. Remove the prism.

ii) Draw a line **PO** such that it makes an angle **i =30°** with the normal **AD**.

iii) Record the angle **i**. Replace the prism on its outline. Place **two** pins **R** and **S** as shown in the diagram. On the opposite side, arrange two pins **T** and **Q** such that the four pins appear to be in a straight line when viewed through the prism. Remove the prism and the pins. Mark the positions of the pins. Join **RS** and **QT** and produce the lines to intersect at the point **K**.

iv) Measure and record the angle of deviation **d**. Repeat the experiment for **i = 40°, 45°, 55°** and **60**^{0} and obtain the corresponding values of d.

v) Tabulate the results.

vi) Plot a graph with d as ordinate and i as abscissa.

vii) Determine $\mathbf{d_m}$ corresponding to the minimum value of **d** and $\mathbf{i_m}$ corresponding to the angle of incidence at minimum deviation

viii) Evaluate $\mu = \frac{\sin\left(\frac{d_m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ where ***A*** is the refracting angle of the triangular glass prism.

ix) Use your graph to find the values of ***i*** at ***d*** = 38.5°

x) State two precautions you took in performing this experiment.

Their responses were presented and analysed in Table 8

Indicators to identify the required science process skills with Task 4 as used in this study.

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skills

The indicators of experimenting skills in Task 4 include the ability to follow step-by-step instructions and correctly set up the apparatus, including the proper placement of pins and the prism. Respondents were expected to carefully place the glass block on its outlined position and accurately trace its outline. Controlling errors was essential, particularly by positioning the pins vertically and aligning them with precision. The task also involved setting specific angles of incidence, placing pins accordingly, and repeating the procedure to ensure reliability. Taking multiple readings was important to minimize random errors. In addition, students were required to document their observations accurately and systematically, for example, by creating a table that displays the angles of incidence and deviation. They were also expected to draw and correctly label the axes, plot the obtained data points, and demonstrate an understanding of the concept and significance of a line of best fit. These actions collectively represent the proper acquisition of experimenting skills.

Measuring skills

The indicators for measuring skills in Task 4 include the respondent's ability to use their protractors accurately to measure the angle of incidence (*i*) and the angle of deviation (*d*), ensuring each measurement is taken carefully from the correct baseline to avoid parallax errors. Measuring skills also involve using a ruler to draw precise lines for the incident and emergent rays, reading graph values, such as identifying the corresponding value of *i* when $d = 38.50°$ and creating neat, organized tables for all measured and calculated values. Together, these actions demonstrate the correct acquisition of measuring skills.

Observing skills

In exhibiting observing skills in Task 4, key indicators include the respondent's ability to follow all steps of the experiment while paying close attention to detail. This includes properly aligning the prism and the light source to ensure accurate measurements, identifying a light source that provides clear images, and avoiding parallax errors. Observing skills also involve maintaining proper alignment of the optical pins R and S with T and Q to ensure accurate image formation, as well as demonstrating precision and consistency in recording data. Additionally, students should be able to observe that an increase in the angle of incidence results in a corresponding increase in the angle of emergence. Other important aspects of observing skills include noticing the shift in the emergent ray, identifying how the angle of deviation changes with different values of *i*, and visually interpreting the point of minimum deviation on the graph. Together, these abilities constitute the correct acquisition of observing skills.

Communicating skills

The indicators for communicating skills in the Task 4 includes drawing and labelling ray diagrams, showing incident and refracted rays, tabulating values of I and d clearly and systematically, drawing a neat, labelled graph of d on y-axis against I on the x-axis, labelling graph axes with correct units and stating values for dm. It also includes results and stating precautions taking in conducting the experiment. These constitute communicating skills in the item given.

Inferring skills

Inferring skills involve the ability to tabulate the values of *i* and *d* clearly and systematically, and to draw a neat, well-labelled graph of *d* (on the y-axis) against *i* (on the x-axis) with the correct units. These skills also include analysing the graph of *d* versus *i* to determine the minimum deviation, using the prism formula to calculate the refractive index, and estimating the value of *i* from a given value of *d*. Additionally, stating two precautions taken during the experiment further demonstrates the correct application of inferring skills

Table 8: *Analysis of Students' Responses to Task 4 of the Intervention Exercises for Week 4*

Science Process Skills	Correct Acquisition of Skills Frequency	Partial Acquisition of Skills Frequency	No Acquisition of Skills Frequency
Experimenting	29(79.25%)	16(16.98%)	8(3.77%)
Measuring	37(69.81%)	12(22.64%)	4(7.55%)
Observing	41(77.36%)	8(15.09%)	4(7.55%)
Communicating	36(67.92%)	13(24.53%)	4(7.55%)
Inferring	31(58.49%)	17(32.08%)	5(9.43%)

Experimenting Skills

Data from Table 8 show that 29 students, representing 79.25%, were able to demonstrate the correct acquisition of experimenting skills. These students arranged the apparatus correctly to ensure accurate measurements, such as aligning the glass block properly before taking measurements. They ensured that there was sufficient light in the laboratory so that the optical pins used could be clearly seen. They made sure that both the object and image pins were upright and straight in order to avoid parallax errors. They carefully traced the path of the incident and emergent rays, took multiple readings to minimize random errors, and documented their observations systematically, such as in a table showing angles of incidence and deviation. They were able to draw and label the axes correctly, plot the obtained points, and demonstrate an understanding of the line of best fit and its significance. This constitutes the correct acquisition of experimenting skills.

On the other hand, 16 students (16.98%) were able to maintain a safe and controlled experimental environment. They comported themselves appropriately within their groups and were able to identify and select the appropriate materials for the task. They demonstrated a basic understanding of the relationship between the angle of incidence and the angle of refraction and documented their observations systematically, such as in a table showing angles of incidence and refraction. They were also able to draw the axes correctly. While they demonstrated a good start, they needed more practice and guidance to achieve consistency, accuracy, and a deeper understanding of experimental design. This constitutes partial acquisition of experimenting skills.

Meanwhile, 8 students (3.77%) were not able to exhibit any meaningful acquisition of experimenting skills, and as such, their responses were classified as no acquisition of skills. These students frequently demanded guidance from the instructor and struggled to perform the key tasks independently.

Measuring Skills

From the data presented, 37 respondents, representing 69.81%, demonstrated correct acquisition of measuring skills. These participants were able to use their protractors to measure the angle of incidence (*i*) and the angle of deviation (*d*) accurately, carefully measuring each angle from the correct baseline to avoid parallax errors. They used rulers to draw precise lines for the incident and emergent rays and accurately read the graph values for $d = 38.50°$ to find the corresponding value of *i*. Additionally, they created neat and organized tables for all measured and computed values. To avoid parallax errors, they ensured they viewed the protractor directly when taking angular measurements, and they maintained consistency in recording their values.

On the other hand, 12 respondents (22.64%) demonstrated some acquisition of measuring skills but not fully. These participants were able to trace the outline, draw the normal, and correctly measure the angle of incidence provided to them. However, they occasionally made errors, particularly with accuracy and omissions in recording their values. While they ensured consistency in their measurements, these challenges resulted in partial acquisition of the measuring skills.

Meanwhile, 4 respondents (7.55%) were unable to demonstrate any meaningful acquisition of measuring skills. These students struggled with aligning the protractor's baseline with the normal line to ensure precise angle measurements. They also had difficulty correctly interpreting the scale on the protractor to record the angle in degrees. Furthermore, they were unable to maintain consistency in their recordings, which led to their responses being classified as showing no acquisition of measuring skills.

Observing Skills

The analysis presented in Table 8 indicates that 38 respondents, representing 71.70%, demonstrated correct acquisition of observing skills. They followed all steps of the experiment carefully and paid close attention to detail. They ensured the proper alignment of the prism and light source for accurate measurements. These respondents were able to identify a light source that provided clear images and took steps to avoid the parallax error. They maintained proper alignment of the optical pins and image throughout the experiment and showed precision and consistency when recording their data.

Additionally, they observed that an increase in the angle of incidence resulted in an increase in the angle of emergence, and they successfully identified the turning point on the graph. In contrast, 8 respondents (15.09%) exhibited some acquisition of observing skills. While they performed the experiment with some accuracy, they often needed guidance to identify and correct misalignment or improper placements in the experimental setup. These respondents showed potential for mastery but required further reinforcement of skills, improved focus, and a deeper understanding of the task, reflecting partial acquisition of observing skills. Meanwhile, 4 respondents (7.55%) demonstrated no meaningful acquisition of observing skills. They relied entirely on others for data collection and showed no improvement despite repeated exposure, demonstrations, and instructions. These respondents exhibited a lack of basic understanding and confidence in completing the task, resulting in their responses being classified as showing no acquisition of the required skills.

Communicating skills

Table 8 shows that 36 participants, representing 67.92%, demonstrated correct acquisition of communication skills. They were able to draw and label ray diagrams accurately, showing both incident and refracted rays. These participants clearly and systematically tabulated the values of i and d, and drew neat, well-labelled graphs of d (on the y-axis) against i (on the x-axis), with correct units. They correctly stated the value of the minimum deviation (d_m), identified relevant precautions taken during the experiment, and presented their findings in a well-structured and coherent manner. Their diagrams were clearly labelled, showing all required points as specified by the question item.

In contrast, 13 participants (24.53%) demonstrated only partial acquisition of communication skills. While they attempted to engage with the tasks, they frequently relied on support from peers and the instructor to clarify their ideas. This indicated a developing but incomplete ability to communicate experimental findings independently. Meanwhile, 4 participants, representing 7.55%, did not show meaningful acquisition of communication skills. They were unable to articulate their observations during the experiment effectively and presented their information in a disorganized and incoherent manner. As a result, their responses were classified as showing no acquisition of the relevant skills.

Inferring Skills

Table 8 shows that 31 respondents, representing 58.49%, were able to tabulate the values of i and d clearly and systematically. They also drew a neat, properly labelled graph of d (on the y-axis) against i (on the x-axis), including correct units. These respondents successfully plotted the graph to determine the minimum deviation and used the prism formula to calculate the refractive index. Additionally, they estimated the value of i corresponding to a given deviation of $d = 38.5°$, and were able to state two precautions taken during the experiment. These activities constitute the correct acquisition of inferring skills.

On the other hand, 17 participants, representing 32.08%, demonstrated only partial acquisition of inferring skills. They were able to tabulate the values of i and d clearly and produced a neat, labelled graph with correct units. However, they encountered difficulties in plotting the graph accurately to determine the minimum deviation. Although they attempted to apply the prism formula to calculate the refractive index, their results were incorrect due to errors in identifying the correct value of the minimum deviation.

Meanwhile, 5 participants (9.43%) did not demonstrate any meaningful acquisition of inferring skills. They struggled throughout the process and were unable to perform the key tasks required for the skill to be considered acquired.

4.4 Post – Intervention Activities

These exercises took place after one week of the intervention period. The aim of these exercises were to evaluate the effect of the intervention strategy implemented on the students' acquisition of science process skills in physics optics. Data collected on students' output in the post-test were analysed and presented as follow:

Task 6: Knowledge of the behaviour of light through Triangular glass block

Students were provided with rectangular glass block, drawing board, drawing paper, optical and thumb pins to perform the following activities as well as the diagram in Fig 7 to aid the

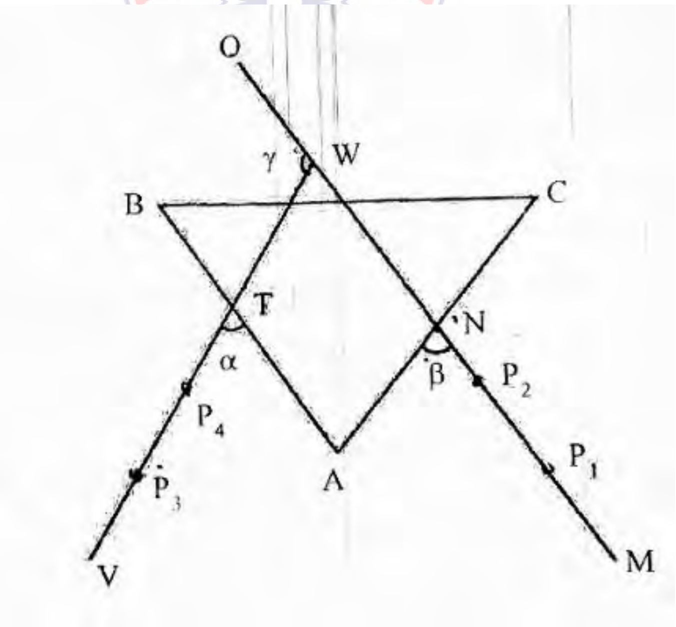


Figure 7: *A diagram showing how light behaviour through triangular prism*

Students were tasked to:

i) Pin the drawing paper onto the drawing board.

ii) Trace the outline ABC of the triangular prism on the drawing paper.

iii) Remove the prism from its trace. Measure and record the refracting angle A.

iv) Select a point N on the side AC of the outline. Draw a straight line MO through N and making a glancing angle ß= 60° with the side AC.

v) Fix two pins at P_1, and P_2, on the line MN. Replace the prism on its outline.

vi) Look through the side AB of the prism and fix two other pins at P_3, and P_4, such that they appear to be in a straight line with the images of the pins at P_1, and P_2,:

vii) Remove the prism and the pins. Join P, and P, with a straight line VT and extend to meet MO at W.

viii) Measure and record angles α and γ.

ix) Evaluate $\theta = (90 - \beta)$, $\varphi = (90 - \alpha)$, $U = (\theta - \varphi)$

x) Repeat the procedure for four other values of ß = 65°, 70°, 75° and 80°. In each case measure α, γ and evaluate θ, φ and U

xi) Plot a graph with y on the vertical axis and U on the horizontal axis, starting both axes from the origin(0, 0)

xii) Determine the slope, s, of the graph.

xiii) State the significance of the slope

xiv) Determine the intercept, C, on the vertical axis.

xv) State two precautions taken to ensure accurate results.

Their responses were analysed and presented in Table 9

Indicators to identify the required science process skills with Task 1 as used in this study

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skills

The indicators for experimenting skills in Task 1 include following step-by-step instructions accurately and setting up the apparatus correctly, including the proper placement of pins and the prism. It is important to ensure that there is sufficient lighting in the laboratory to allow for clear visibility during the experiment. The glass block should be carefully placed on its outlined position and its outline traced accurately. Errors should be controlled by positioning the pins vertically and aligning them with precision. The glancing angle, β, should be systematically varied (e.g., 60°, 65°, 70°, etc.) while keeping other variables constant. For each value of β, the procedure should be repeated for different values of the angle of incidence, α. After collecting the data, the axes should be drawn and labelled correctly on the graph, the obtained points plotted accurately, and an appropriate line of best fit drawn.

Measuring skills

The indicators for measuring skills in Task 1 include respondents correctly using their protractors to measure angle A of the prism, as well as accurately measuring the angles α and γ after tracing the emergent and refracted rays. They should also be able to calculate derived quantities accurately, such as $\theta = 90° - \beta$ and $\varphi = 90° - \alpha$. In addition, they are expected to create neat and organized tables that clearly present all measured and calculated values. These activities collectively demonstrate the required measuring skills.

Observing skills

In exhibiting this skill, the indicators includes respondents sighting through the prism and visually aligning pins P_3 and P_4 with the images of P_1 and P_2, noticing the changes in the emergent ray's direction as $\boldsymbol{\beta}$ increases, recognising the changing angle patterns and how ray deviation varies.

Communicating skills

The indicators for communicating skills in the Task 1 includes drawing and labelling ray diagrams, showing incident and refracted rays, recording values of β, α, γ, θ, φ and U clearly in a well-structured table, drawing a neat, labelled graph of y on y-axis against U on the x-axis, labelling graph axes with correct units and stating values for dm. It also includes writing explanations of the slope and the intercept's significance and stating precautions taking in conducting the experiment. These constitute communicating skills in the item given.

Inferring skills

Inferring skills involve the ability to analyse how changes in the glancing angle β affect angle α and the derived quantity U. They include plotting a graph of *y* versus *U* and interpreting the relationship between these variables. Learners should be able to use the graph to determine the slope, which shows how *y* changes with *U*, and identify the intercept for extrapolation. They should also understand what the slope represents in the context of light deviation through a prism.

Table 9: *Analysis of Students' Responses to Task 1 of the Post-Intervention Exercises for Week 6*

Science Process Skills	Correct Acquisition of Skills Frequency	Partial Acquisition of Skills Frequency	No Acquisition of Skills Frequency
Experimenting	39(73.58%)	12(22.64%)	2(3.77%)
Measuring	45(84.91%)	7(13.21%)	1(1.89%)
Observing	48(90.57%)	5(9.43%)	-
Communicating	47(88.68%)	6(11.32%)	-
Inferring	38(71.70%)	10(18.87%)	5(9.43%)

Experimenting skills

The data presented show that 39 students (73.58%) demonstrated full acquisition of experimenting skills. These students correctly arranged the apparatus to ensure accurate measurement, such as properly aligning the glass block before taking measurements. They also ensured that there was sufficient lighting in the laboratory and that both the object and image pins were erect and straight to avoid parallax error. Furthermore, they systematically varied the glancing angle β (e.g., 60°, 65°, 70°, etc.) while keeping other variables constant, and correctly determined the corresponding values of α through successful repetition of the given procedure. These students were able to draw and label the axes correctly, plot the obtained points, and accurately draw the line of best fit. These actions collectively indicate a correct acquisition of experimenting skills.

Twelve students (22.64%), on the other hand, demonstrated partial acquisition of the skills. Although they were able to arrange the apparatus correctly, align the glass block properly, and ensure that the object and image pins were straight to avoid parallax error, they relied on assistance from their peers and the facilitator. Nonetheless, they carefully traced the path of the incident and emergent rays and were able to draw and label the axes correctly. In contrast, two students (3.77%) demonstrated no acquisition of experimenting skills.

Measuring skills

The analysis presented in Table 9 indicates that the majority of participants had acquired measuring skills. Forty-five respondents (84.91%) demonstrated correct acquisition of measuring skills. These students were able to accurately measure the required angles using a protractor, as outlined in Activities iii and iv. They successfully constructed tables of values, including appropriate units and clearly indicated least count. Additionally, they ensured consistency in recording their measurements and organized their data in a clear and logical manner. These actions collectively reflect correct acquisition of measuring skills.

On the other hand, seven respondents (13.21%) exhibited partial acquisition of measuring skills. While they demonstrated some ability to carry out measurements and organize their data, they encountered challenges in recording values with the appropriate least count and frequently relied on assistance from their peers. These shortcomings resulted in their classification under partial acquisition of measuring skills. Only one student (1.89%) did not demonstrate any acquisition of measuring skills.

Observing skills

The analysis presented in Table 9 indicates that all respondents acquired some level of observing skills. A total of 48 students (90.57%) demonstrated full acquisition of observing skills. These students ensured proper alignment of the prism and light source for accurate measurements. They were able to identify the appropriate light source that provided clear images and took steps to avoid parallax error. Additionally, they maintained correct alignment of optical pins, as outlined in Activity VI, and demonstrated precision and consistency in recording their data.

Conversely, five students (9.43%) demonstrated partial acquisition of observing skills. Although they participated in the experiment, they frequently relied on support from their peers to complete the required tasks.

Communicating skills

Table 9 shows that 47 participants (88.68%) fully demonstrated the acquisition of communication skills. These students actively shared their observations and ideas clearly and respectfully. They presented their findings in a well-structured manner, using appropriate scientific terminology. Their diagrams were clearly labelled, showing all relevant points as required by Activities IV and V. Additionally, they effectively articulated the procedures used in tracing the image of the optical pins within the glass prism. They accurately evaluated the derived quantities: $\theta = (90° - \beta)$, $\varphi = (90° - \alpha)$, and $U = (\theta - \varphi)$. They were also able to state appropriate precautions necessary for improving experimental accuracy. These competencies collectively represent the correct acquisition of communication skills.

On the other hand, six respondents (11.32%) were classified as having partial acquisition of communication skills. While they also presented their findings in a structured manner, correctly labelled their diagrams, and accurately evaluated θ, φ, and U, they frequently required clarification and assistance to carry out the experiment. This reliance indicated a less independent demonstration of communication skills.

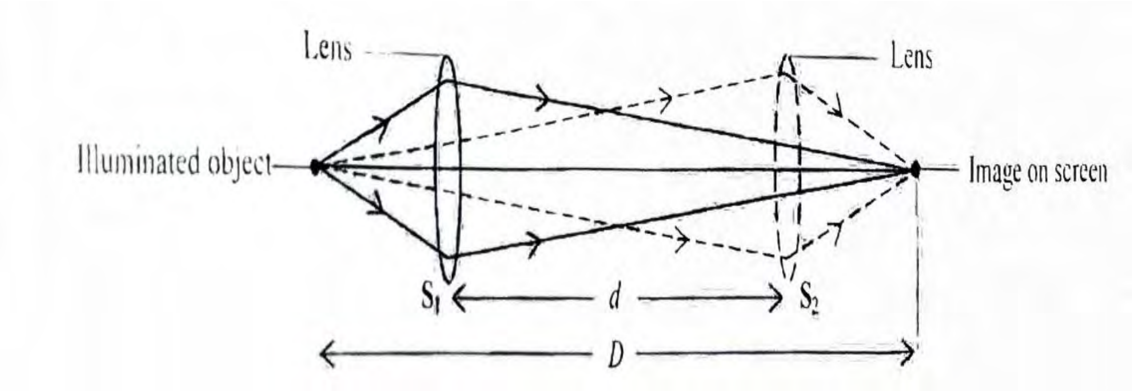
Inferring skills

The data presented in Table 9 show that inferring skills were the least acquired among the measured skill categories. Out of the 53 participants, 38 students (71.70%) demonstrated full acquisition of inferring skills. These students correctly plotted the graph with *y* on the vertical axis and *U* on the horizontal axis, starting both axes from the origin (0, 0). They were able to analyse, interpret, and explain the significance of the slope obtained, demonstrating a deeper understanding of optical principles. These abilities constitute the correct acquisition of inferring skills.

In contrast, 10 students (18.87%) were classified as having partial acquisition of inferring skills. Although they successfully plotted the graph with the correct axes and origin, they were unable to analyse, interpret, or explain the significance of the slope in relation to the principles of optics. This limited understanding reflects partial acquisition of the skill.

Finally, five students (9.43%) were unable to demonstrate any meaningful acquisition of inferring skills. Their responses lacked evidence of understanding or application, and were therefore classified as no acquisition of inferring skills.

Figure 8: Knowledge of focal length of a lens using displacement method



Respondents were provided with an illuminated object, a lens, a screen, a lens holder and a mere rule to perform the following activities as well as the diagram in Fig. 8.

Figure 8: A diagram showing how focal length is determined using displacement method.

Students were to tasked to:

i) Determine the approximate focal length, ***f***. of the lens by focusing a distant object on the screen.

ii) Place the illuminated object and the screen a distance D = 100 cm apart.

iii) Place the lens at a position **S**, to obtain a sharp image of the object on the screen. Note **S_1**,

iv) Move the lens to a position **S**, to obtain another sharp image of the object on the screen. Note S_2,

v) Measure the distance, d, between S_1, and S_2,.

vi) Evaluate D^{-1}, D^{-2}, d^2 and $\frac{d^2}{D^2}$

vii) Repeat the procedure for four other values of D = 90 cm, 85 cm, 80 cm and 70 cm.

viii) Tabulate the results. In each case, evaluate D^{-1}, D^{-2}, d^2 and $\frac{d^2}{D^2}$

ix) Plot a graph with $\frac{\boldsymbol{d^2}}{\boldsymbol{D^2}}$ on the vertical axis and D^{-1} on the horizontal axis.

x) Determine the slope, s, of the graph.

xi) State the significance of the slope

xii) Given that s = 4k, determine k.

xiii) State two precautions taken to ensure accurate results, b)

i) Draw and label the ray diagram of a simple microscope.

ii) State two differences between a real image and a virtual images.

Their responses were analyses and presented in Table 11.

Indicators to identify the required science process skills with Task 2 as used in this study

Operational definition of indicators for the acquisition of science process skills in this study are:

Experimenting skills

The indicators of experimenting skill in Task 2 includes following step-step instructions, setting up the object and the screen 100 cm apart, adjusting the lens to find two sharp image positions S_1 and S_2, repeating the procedure for other D values, 90 cm, 85cm, 80 cm, and 70 cm, plotting a graph with calculated values.

Measuring skills

The indicators for measuring skills for Task 2 includes respondents using estimating the focal length by focusing a distant object, measuring the distance d between S_1 and S_2, calculating values, creating a neat, organised tables for all measured and computed values, determining the slope of the graph.

Observing skills

In exhibiting this skill in Task 2, the indicators includes respondents observing when the image is sharply focused, observing and recording S_1 and S_2 positions, carefully observing ray behaviour while drawing and labelling the ray diagram of a simple microscope in item b(i).

Communicating skills

The indicators for communicating skills in the Task 2 includes creating a well-organised table of results, labelling graph axes with correct units, drawing and labelling a ray diagram of a simple microscope, explaining the significance of the slope and using the given relationship to find the value of K. These constitute communicating skills in the item given.

Inferring skills

The inferring skills constitute the ability to interpret the meaning of the graph's slope, calculating K from S = 4 k, stating the difference between a real and virtual image. The responses of the respondents were analysed and presented in Table 10.

Table 10: *Analysis of Students' Responses to Task 2 of the Post-Intervention Exercises for week 7*

Science Process Skills	**Correct Acquisition of Skills**	**Partial Acquisition of Skills**	**No Acquisition of Skills**
	Frequency	**Frequency**	**Frequency**
Experimenting	46(88.68%)	7(13.21%)	
Measuring	49(92.45%)	4(7.55%)	
Observing	51(94.34%)	2(3.77%)	
Communicating	50(94.34%)	3(5.66%)	
Inferring	43(81.13%)	9(16.98%)	1(1.89%)

Experimenting skills

The data presented in Table 10 show that 46 participants (86.79%) fully demonstrated the acquisition of experimenting skills. These students correctly arranged the apparatus to ensure accurate measurements and ensured that there was sufficient lighting in the laboratory. They successfully drew and labelled the axes on their graphs, accurately plotted the data points obtained, and correctly constructed the line of best fit. These actions constitute the correct acquisition of experimenting skills.

Seven students (13.21%) were classified as having partial acquisition of experimenting skills. While they were able to arrange the apparatus correctly and label the axes accurately, they relied on support from their peers and the facilitator to complete the tasks. This dependence indicates that, although they demonstrated some proficiency, their acquisition of the skill was not complete.

None of the students were classified as having no acquisition of experimenting skills. All participants demonstrated at least some level of competency in experimenting skills

Measuring skill

The analysis presented in Table 10 indicates that the majority of participants acquired measuring skills. 49 respondents (92.45%) demonstrated correct acquisition of measuring skills. These students accurately placed the illuminated object and the screen at a distance of $D = 100$ cm apart. They were able to measure the distance d between S_1 and S_2 with precision. Additionally, they constructed tables of values with appropriate units and clearly indicated the least count. The students ensured consistency in recording their measurements and organized their data in a clear and logical manner. They also drew and labelled the ray diagram of a simple microscope, as required in Task 7b(i). These competencies collectively indicate correct acquisition of measuring skills.

Conversely, 4 respondents (7.55%) demonstrated partial acquisition of measuring skills. Although they participated in the activities, they consistently relied on assistance from their peers to complete the tasks, indicating an incomplete mastery of the skills involved

Observing skill

Observing skill was the science process skill most frequently demonstrated by the students. The analysis presented in Table 10 indicates that 51 students (96.23%) demonstrated full acquisition of observing skills, while only two respondents (3.77%) demonstrated partial acquisition. The 51 students were able to determine the approximate focal length (*f*) of the lens by focusing a distant object onto a screen. They correctly positioned the lens at S_1 to obtain a sharp image of the object and accurately recorded the position.

In contrast, 2 respondents classified as having partial acquisition of observing skills were unable to correctly determine the approximate focal length of the lens, indicating incomplete understanding and application of the procedure.

Communicating skills

Table 10 shows that 50 participants (94.34%) fully exhibited communicating skills. These students presented their findings in a well-structured manner and were able to state the precautions necessary to improve accuracy, which reflects their correct acquisition of communicating skills. They were able to place the lens at position S to obtain a sharp image of the object on the screen, correctly noting S_1. Additionally, they successfully evaluated D^{-1}, D^{-2}, d^2, and d^2/D^2, further demonstrating their competence in communicating skills.

In contrast, three respondents (5.66%) were unable to fully exhibit the communicating skills. While they also presented their findings in a well-structured manner, they frequently required clarification and support to perform the experiment. This dependence indicates partial acquisition of the communicating skills.

Inferring skills

The data presented in Table 10 show that inferring skills were the least acquired among the skills measured, although there was improvement in its acquisition compared to previous activities. Out of the 53 participants, 43 students (81.13%) demonstrated full acquisition of inferring skills. These students were able to correctly plot the graph with d^2/D^2 on the vertical axis and D^{-1} on the horizontal axis, as outlined in Task 7a(ix). They successfully determined the slope, interpreted it, and explained its significance, demonstrating a deeper understanding of optics principles, as indicated in Tasks 7a(x) and 7a(xi), respectively.

However, nine respondents (16.98%) exhibited partial acquisition of inferring skills. These students were able to determine the significance of the slope but did not fully demonstrate the depth of understanding required. They were able to were able to correctly plot the graph with d^2/D^2 on the vertical axis and D^{-1} on the horizontal axis, as indicated in Task 7a(ix). They successfully determined the slope but failed to give proper interpretation to the slope and its significance. Which constituted partial acquisition of inferring skills. One respondent (1.89%) showed no acquisition of inferring skills.

Table 11: *The number of students correctly acquiring the science process skills through Frequent Laboratory Practical Activities within the four weeks of intervention period.*

Science Process skills		Number of Students with correct acquisition of skills for the four weeks of intervention			
		Week 1	**Week 2**	**Week 3**	**Week 4**
1.0	Experimenting	15	19	23	29
2.0	Measuring	19	21	34	37
3.0	Observing	24	29	38	41
4.0	Communicating	18	23	30	36
5.0	Inferring	12	18	24	31

As shown in Table 11, there was a progressive increase in the number of students acquiring all five science process skills throughout the five-week intervention. For example, the number of students demonstrating experimenting skills correctly rose from 10 students in Week 1 to 29 in Week 4. Measuring skills improved from 13 to 37 students, and observing skills showed the highest growth, increasing from 16 to 41. Similarly, communicating skills increased from 15 to 36, and inferring skills grew from 8 to 31. These findings are consistent with previous studies that affirm the positive impact of frequent laboratory activities on the acquisition of science process skills. For example, Akinbobola and Afolabi (2010) found that students who regularly participate in hands-on laboratory experiences demonstrate higher proficiency in process skills compared to those taught using traditional lecture methods. Similarly, Ofuani (as cited in Reeves & Crippen, 2021) found that guided-inquiry laboratory activities significantly enhanced students' skills in observing, measuring, and experimenting. The sharp increase in observing and measuring skills may be attributed to frequent feedback after each laboratory practical activity provided. Hence, they require continuous visual attention and precise measurement skills that are honed through repetition and reflection as a result of the feedback improved on their skills acquisition (Yusuf & Afolabi, 2010). Although the growth in inferring and communicating skills was slightly less, it still suggests that interpretative and expressive skills can also be developed when students engage collaboratively in lab-based tasks, as noted by Malik and Ubaidillah (2021). Students were taken through post-intervention laboratory practical activities for two weeks aimed at evaluating the effectiveness of the intervention on their acquisition of science process skills. These exercises were important not only for assessing individual student progress but also for determining the overall impact of the intervention on the skills acquisition. The result is demonstrated in Table 12.

Table 12: *The number of students demonstrating the correct acquisition of science process skills in Post-Intervention activities for weeks 6 and 7*

Science process skills	Number of Students demonstrating correct acquisition of skills for post-intervention activities	
	Week 5	Week 6
1. Experimenting	39	46
2. Measuring	45	49
3. Observing	48	51
4. Communicating	47	50
5. Inferring	38	43

Table 12 reveals a consistent upward trend in all five science process skills from Week 5 to Week 6. The number of students acquiring experimenting skills increased from 39 to 46, indicating an improved ability to design and carry out experiments. Measuring skills rose from 45 to 49, and observing skills, which had already been the most commonly acquired skill, increased from 48 to 51 students. Similarly, communication skills improved from 47 to 50 students, while inferring skills increased from 38 to 43 students. The results indicate that not only did the intervention lead to immediate gains, but the skills were also progressively retained during the intervention period. This demonstrates the effectiveness of frequent laboratory practical activities in fostering the acquisition of science process skills. This continued growth supports the theory that frequent exposure to practical activities facilitates both the acquisition and reinforcement of science process skills (Ngozi, 2021). Furthermore, it can be deduced that the steady increase across all the skills suggests that students internalized the processes through repetition and continued application, leading to higher competence even after the formal intervention had concluded.

Additionally, the improvement in skills such as observing and measuring in Weeks 5 and 6 may reflect a high level of proficiency in these competencies, which are essential for laboratory activities. These findings corroborate earlier research that emphasizes the role of long-term laboratory engagement in fostering scientific competencies (Akinbobola & Afolabi, 2010).

To evaluate the effectiveness of frequent laboratory practical activities on students' acquisition of science process skills, a comparison was made between the results obtained in Week 4 of the intervention and those recorded in Week 6 of the post-intervention laboratory practical activities. This comparison aimed to determine the number of students who demonstrated proficiency in acquiring science process skills at both time points. The observed improvements in the number of students who acquired these skills between Week 4 and Week 6 underscore the critical role of frequent laboratory practical activities in science education. This progression is significant because it provides empirical evidence that sustained engagement in hands-on learning environments enhances students' ability to acquire essential science process skills. The results are presented in Table 13.

Table 13: *Comparison of number of students acquiring the correct science process skills at the end of Intervention and Post-Intervention (weeks 4 and 6) activities respectively*

Science process skills	**Pre-Intervention results Week 4**	**Post-intervention results Week 6**
Experimenting	29	49
Measuring	37	49
Observing	41	51
Communicating	36	50
Inferring	31	43

The Table 13 reveals significant improvement in the number of students who correctly acquired science process skills from the end of the intervention in Week 4 to the post-intervention assessment in Week 6. Experimenting skills increased from 29 to 46 students, measuring skills from 37 to 49, and observing skills from 41 to 51. Similarly, communicating skills and inferring skills improved significantly, from 36 to 50 and 31 to 43, respectively.

This substantial growth in science process skills acquisition in post-intervention suggests that the effect of laboratory practical activities was not per chance but also sustainable over time. The post-intervention results showing a further increase in acquisition of science process skills supports previous findings that frequent hands-on experiences lead to deeper understanding and better retention of scientific competencies (Golosino & Paglinawan, 2024).

4.5 Discussion of Results

The findings of this research were further discussed to answer questions that guided the study.

4.5.1 Research Question 1

What are the extent of science process skills of Form Two Senior High School science students in the Begoro Presbyterian Senior High before being exposed to frequent laboratory practical activities?

The aim of this question was to determine how many students improved their science process skills after being exposed to frequent laboratory practical activities. The findings revealed that students' acquisition of science process skills began to improve once the intervention strategy was introduced. To examine the impact of practical activities on students' acquisition of science process skills in selected topics in optics, the number of students who demonstrated correct acquisition of skills in the pre-test was compared with the results obtained during the intervention exercises and the post-test. The pre-test results indicated that many students lacked the required science process skills in the selected optics topics before the implementation of the intervention strategy. A large proportion of their responses to the pre-test items were incorrect, suggesting that they had not yet developed the necessary skills required for practical activities in those topics.

These findings provide clear evidence of the importance of frequent laboratory practical activities in enhancing students' acquisition of science process skills. The participants' performance in the post-intervention exercises, as presented in Tables 5 and 6, further demonstrates that science process skills can be effectively developed through regular hands-on laboratory experiences.

This finding supports the observation made by Chukelu (2009), who reported that the practical activity method was more effective in promoting students' acquisition of science process skills than the lecture method. Similarly, Akinbobola and Afolabi (2010) also observed that frequent laboratory practical activities contribute significantly to the development of these essential skills. Furthermore, Efe and Abamba (2023) examined the effects of laboratory methods on senior secondary school students' acquisition of science process skills in chemistry in Delta State. Their study revealed that students taught through laboratory-based methods performed significantly better than those taught using the traditional lecture method, showing a 74% improvement in science process skills.

However, the findings of the present study contradict those reported by Okinuga, Ojo, and Yande (2013), who found that laboratory activities led to low acquisition of science process skills such as observation, interpretation, inferring, communication, prediction, and experimentation. A possible reason for this discrepancy may be that inadequate equipment in some settings limits students' opportunities for active participation in hands-on laboratory activity, thereby reducing the effectiveness of practical activities in skill acquisition.

Despite the contradiction between the finding in this current study and that of Okinuga, Ojo, and Yande, more studies do confirm the effectiveness of frequent laboratory practical activities on the acquisition of science process skills.

4.5.2 Research Question 2

What are the extent of science process skills of Form Two Senior High School science students in the Begoro Presbyterian Senior High before being exposed to frequent laboratory practical activities?

The research question sought to determine the extent of science process skills of Form Two Senior High School science students of Begoro Presbyterian Senior High School after being exposed to frequent laboratory practical activities. The analysis was based on data obtained from the post-intervention phase presented in Table 12

Results from the post-intervention activities indicate a marked improvement and high extent of acquisition of science process skills among the students. For *experimenting* skills, 39 students demonstrated correct acquisition in Week 5, which increased to 46 students in Week 6. This suggests that repeated exposure to laboratory practical activities significantly enhanced students' ability to design and carry out experiments independently.

Similarly, *measuring* skills recorded high levels of acquisition, with 45 students correctly acquiring the skill in Week 5 and 49 students in Week 6. This improvement reflects increased student competence in the use of measuring instruments and accurate data collection following sustained practical engagement. *Observing* skills showed the highest level of acquisition, with 48 students demonstrating correct acquisition in Week 5 and 51 students in Week 6, indicating strong development of students' ability to notice, identify, and describe scientific phenomena accurately.

In the area of *communicating*, 47 students demonstrated correct acquisition of the skill in Week 5, which increased to 50 students in Week 6. This improvement suggests enhanced ability among students to record results, explain observations, and present experimental findings clearly. *Inferring* skills also showed substantial improvement, with **38** students correctly acquiring the skill in Week 5 and 43 students in Week 6, indicating improved capacity to draw logical conclusions from observed data.

Overall, the post-intervention results indicate that the majority of students successfully demonstrated the correct acquisition of all the science process skills assessed. This suggests a high level of science process skill development following their exposure to frequent laboratory practical activities. The consistent rise in the number of students who showed correct acquisition of these skills in Weeks 5 and 6 further indicates that continuous participation in laboratory activities helps to strengthen and reinforce these competencies.

These findings are consistent with earlier studies that have reported substantial improvements in students' science process skills as a result of frequent and well-structured laboratory practical activities. Padilla (1990) noted that science process skills are most effectively developed through active participation in scientific investigations rather than through purely theoretical instruction. In a similar vein, Rezba et al. (2007) reported that repeated hands-on laboratory experiences significantly improve students' abilities in observing, measuring, experimenting, and making inferences. Harlen (2010) also observed that inquiry-based and practical approaches to science teaching promote higher levels of science process skill development among secondary school students.

A similar observation was made by Antwi, Sakyi-Hagan, Addo-Wuver, and Asare (2021) in a study conducted in the Kwaebibirem Municipality in the Eastern Region of Ghana. Their findings revealed that exposing students to laboratory practical activities enhanced the acquisition of science process skills among science students. Based on their results, they recommended that physics teachers should incorporate practical activities into their lessons as an instructional strategy for teaching scientific concepts. The findings of the present study therefore reinforce the view that frequent laboratory practical activities play a significant role in promoting the meaningful development of science process skills among students.

4.5.3 Research Question 3

What is the correlation between the frequency of laboratory practical activities and the acquisition of science process skills in physics among students?

Understanding the link between instructional strategies and students' improvement in the acquisition of science process skills is essential for enhancing the quality of science education. This research question aimed to investigate whether a significant relationship exists between the frequency of laboratory practical activities and students' improvement in science process skills**,** particularly in the area of physics optics.

To examine this relationship, the study compared the number of students who correctly demonstrated the acquisition of science process skills in the pre-test with those who demonstrated these skills in the post-test after the intervention. In other words, the analysis focused on the number of students who showed correct acquisition of the required skills before and after the implementation of the intervention strategy. This comparison made it possible to determine whether frequent laboratory practical activities influenced students' improvement in science process skills.

Table 14 presents number of students showing improvement in the correct acquisition of skills obtained in the pre-test and post-test assessments.

Table 14: *The number of students demonstrating the correct acquisition of skills for pre-intervention and post-intervention exercises*

Skill	Pre-test score	Post-test score
Experimenting	10	46
Measuring	13	49
Observing	16	51
Communicating	15	50
Inferring	8	43

The relationship between frequent laboratory practical activities and students' acquisition of science process skills was analysed using Pearson's correlation analysis. The results revealed a very strong positive correlation (r = 0.987) between the pre-test and post-test scores. This indicates that as students engaged in more laboratory practical activities, their science process skills improved significantly. The skills assessed included experimenting, measuring, observing, communicating, and inferring.

These findings suggest that regular hands-on laboratory experiences are strongly associated with improved acquisition of science process skills, highlighting the effectiveness of practical interventions in physics education (Creswell, 2014). The result also provides justification for rejecting the null hypothesis that frequent laboratory practical activities have no significant effect on students' science process skills. This positive outcome is particularly important in the study of physics optics, where the understanding of complex concepts such as refraction, diffraction, and interference often depends on hands-on experimentation and visual observation for effective comprehension.

The findings are consistent with earlier studies that emphasize the importance of hands-on learning in science education (Hofstein & Lunetta, 2004; Abrahams & Millar, 2008). For instance, Wieman and Perkins (2005) reported that active involvement in laboratory activities helps students visualize and better understand abstract scientific concepts. Through structured experimental activities, students gain deeper insight into the fundamental principles of optics, thereby improving their problem-solving and critical-thinking abilities.

The results of the present study also support previous research that has highlighted the importance of laboratory practical activities in promoting science process skills. For example, Apeadido, Opoku-Mensah, and Mensah (2023) investigated the impact of practical activities on students' science process skills and academic performance. Their findings revealed that integrating practical activities into biology lessons enhanced students' acquisition of science process skills and improved their academic performance. Similarly, Abrahams and Millar (2008) reported that regular engagement in laboratory activities improves students' ability to formulate hypotheses, observe scientific phenomena, and draw valid conclusions. Hofstein and Lunetta (2004) further noted that laboratory experiences provide students with opportunities to develop investigative skills and conceptual understanding in physics.

In addition, a study conducted by Etkina et al. (2010) highlighted the importance of laboratory practical work in developing both procedural and analytical competencies. Their findings showed that students who frequently participate in laboratory activities become more skilled in handling laboratory equipment, taking accurate measurements, and drawing appropriate scientific conclusions. The findings of the present study support these observations and reinforce the view that students exposed to regular laboratory practical activities demonstrate improved acquisition of science process skills and a better understanding of physics concepts.

The strong positive correlation observed in this study suggests that incorporating frequent laboratory activities into physics instruction can significantly enhance students' science process skills. This finding supports educational policies that promote experiential learning approaches in Science, Technology, Engineering, and Mathematics (STEM) education. Furthermore, the results reinforce the constructivist learning theory, which proposes that knowledge is best acquired through active participation and hands-on experiences (Piaget, 1972).

Similarly, Abbey-Kalio (2024) reported that students exposed to laboratory-based teaching methods demonstrated significantly higher levels of science process skill acquisition than those who were taught without practical engagement. The study emphasized that frequent and well-structured laboratory activities contribute to improved science learning outcomes. In the same vein, Hinson (2023) examined the influence of practical work on science process skills and critical thinking among senior high school chemistry students. The results indicated consistent improvement in students' science process skills and academic performance, further confirming the value of regular laboratory activities in enhancing students' cognitive and manipulative skills.

Another study conducted by Issah, Baalongbuoro, and Oware (2023) at Queen of Peace Senior High School revealed that students' poor academic performance in biology was partly attributed to limited exposure to laboratory practical experiences. The researchers concluded that practical activities are essential for improving students' understanding of scientific concepts and their acquisition of science process skills. Furthermore, Özmen (2008) reported that laboratory-based learning environments promote greater student engagement and better retention of science process skills, particularly in areas such as hypothesis formation and drawing conclusions.

Similar outcomes have also been observed in other science disciplines. For example, a longitudinal study by Hofstein et al. (2005) found that students who participated in weekly chemistry laboratory sessions developed stronger analytical abilities, including data interpretation and error analysis, compared with those taught through traditional classroom methods. These findings suggest that the benefits of laboratory activities extend across various scientific disciplines.

The findings of this study therefore add to the growing body of research supporting the use of frequent laboratory practical activities as an effective strategy for improving the acquisition of science process skills. Consequently, there is strong empirical evidence to support the view that regular laboratory practical activities play a critical role in developing students' science process skills. These skills are essential for academic achievement, scientific literacy, and future careers in STEM fields. It is therefore recommended that science educators prioritize the integration of regular, structured, and well-supported laboratory activities in their teaching.

Testing null hypothesis H$_{01}$: Frequent laboratory practical activity has no effect on the acquisition of students' science process skills.

Table 15 presents the mean and standard deviation of the number of students who demonstrated improvement in the correct acquisition of skills during pre-test and post-test assessment and Table presents summary of Repeated Measures ANOVA on the Effect of Frequent Laboratory Practical Activities on Students' Science Process Skills.

Table 15: *Presents the mean and standard deviation of the number of students who demonstrated the correct acquisition of skills during pre-test and post-test assessment*

Assessment Point	Mean (M)	Standard Deviation (SD)
Pre-test	12.4	3.1
Intervention Week 1	17.6	3.5
Intervention Week 2	22.0	4.0
Intervention Week 3	29.8	4.3
Intervention Week 4	34.8	4.5
Post-intervention test 1	43.4	3.9
Post-intervention test 2	47.8	3.7

Table 16: *Summary of Repeated Measures ANOVA on the Effect of Frequent Laboratory Practical Activities on Students' Science Process Skills*

Source	F	df	p-value	Decision
Between Assessments	245.67	6, 24	< 0.001	Reject H_0

Not Significant at $P > 0.05$ level of significance

nt laboratory practical activities on improving students' science process skills. The results indicated statistically significant differences among the pre-test, weekly intervention, and post-test mean scores, F(6, 24) = 245.67, p < 0.001. The post-test mean (M = 47.8, SD = 3.7) was substantially higher than the pre-test mean (M = 12.4, SD = 3.1), indicating a progressive improvement in skills across the intervention period.

Therefore, the null hypothesis, which stated that frequent laboratory practical activities have no significant effect on students' acquisition of science process skills, was rejected. These results demonstrate that frequent, guided, and supervised laboratory practical activities significantly enhance students' competence in performing science processes such as experimenting, observing, measuring, inferring, and communicating (Creswell, 2014)

4.5.3 Research Question 3

What are the students' perceptions toward frequent laboratory practical activities on the acquisition of science process skills?

Research Question Three was meant to investigate students' perceptions regarding frequent laboratory practical activities on the acquisition of science process skills. To gather data, a structured questionnaire was administered to participants, who were asked to respond to a series of statements (see Appendix B).

A four-point Likert scale was used for the analysis, with response options structured as follows: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree. The midpoint value of the scale (2.5) was calculated and used as the threshold for interpreting the responses. A mean score below 2.5 indicated general disagreement to the statement. Conversely, a mean score above 2.5 indicated general agreement to the statement. A score equal to 2.5 reflected a neutral stance, indicating that students neither agreed nor disagreed with the statements.

This interpretive framework aligns with the recommendation of Boone and Boone (as cited in Tanujaya, Prahmana, & Mumu, 2022), who emphasized the importance of using midpoints in Likert-type scales to determine the directional tendency of participants' attitudes. The results of students' responses were computed and presented in Table 15 in percentages of students in each categories and Table 14 represents mean response of students to a given statement. However, Table 14 was focused for discussion of typical characteristic of the students.

Table 14: *Students' perceptions toward frequent laboratory practical activities on the acquisition of science process skills*

		Strongly Disagreed		Disagreed		Agreed		Strongly Agreed	
	Item	Frequency	%	Frequency	%	Frequency	%	Frequency	%
1	Frequent laboratory practical activities have helped me develop my observing skill	-		6	11.32	32	60.38	15	28.30
2	I have improved my measuring skills through laboratory practical activities in physics optics	-		4	7.54	26	49.06	23	43.40
3	I feel more confident in my ability to carry out experiment after participating in frequent laboratory practical activities physics optics	-		1	1.89	10	18.87	42	79.24
4	I have improved my communication skills through frequent laboratory practical activities in physics optics	-		3	5.66	39	73.58	11	20.76
5	Frequent laboratory practical activities have increased my interest in learning physics optics	2	3.77	2	3.77	29	54.72	20	37.74
6	Frequent laboratory practical activities have improved my curiosity in learning of physics optics	7	13.21	9	16.98	21	39.62	16	30.19
7	Frequent laboratory practical activities have improved my motivation in learning of physics optics	-		5	9.43	31	58.49	17	32.08
8	I get excited whenever we perform practicals and I wish we do practicals every day during physics lessons	-		-		4	7.55	49	92.45
9	Frequent laboratory practical activities clarify the content taught through lecture in physics classroom	4	7.55	12	22.64	27	50.94	10	18.87
10	Frequent laboratory practical activities have helped me develop my critical thinking skills	2	3.77	5	9.43	31	58.49	15	28.31

		Strongly Disagreed		Disagreed		Agreed		Strongly Agreed	
	Item	Frequency	%	Frequency	%	Frequency	%	Frequency	%
11	Frequent laboratory practice helps me make logical inference from data	5	9.43	12	22.64	28	52.83	8	15.10
12	I am able to express my ideas and analyse situations very well after performing series of practical activities	8	15.10	5	9.43	30	56.60	10	18.87
13	I understand measurement error better due to frequent laboratory experience	-		-		28	52.83	25	47.17
14	Frequent laboratory practical activities have improved my ability to use scientific instrument	-		-		39	73.58	14	26.42

Table 15: *A table showing mean scores and standard deviations of students' responses to the questionnaire items with mean value arranged in descending order*

	Statement	Mean Score	S.D
1	I get excited whenever we perform practicals and I wish we do practicals every day during physics lessons	3.92	0.26
2	I feel more confident in my ability to carry out experiment after participating in frequent laboratory practical activities physics optics	3.77	0.46
3	I understand measurement error better due to frequent laboratory experience	3.47	0.50
4	Frequent laboratory practice helps me make logical inference from data	3.40	0.74
5	I have improved my measuring skills through laboratory practical activities in physics optics	3.36	0.62
6	I am able to express my ideas and analyse situations very well after performing series of practical activities	3.36	0.89
7	Frequent laboratory practical activities have increased my interest in learning physics optics	3.26	0.70
8	Frequent laboratory practical activities have improved my ability to use scientific instrument	3.26	0.44
9	Frequent laboratory practical activities have improved my motivation in learning of physics optics	3.23	0.60
10	Frequent laboratory practical activities have helped me develop my observing skills	3.17	0.61
11	I have improved my communication skills through frequent laboratory practical activities in physics optics	3.15	0.49
12	I am more capable of modifying experimental procedures when needed due to my frequent laboratory practice	3.11	0.72
13	Frequent laboratory practical activities have improved my curiosity in learning of physics optics	2.87	0.98
14	Frequent laboratory practical activities clarify the content taught through lecture in physics classroom	2.81	0.68

(3.22)

(0.62)

The results revealed an overwhelmingly positive perception of frequent laboratory practical activities. For example, the item "I get excited whenever we perform practicals and I wish we do practicals every day during physics lessons" had the highest mean score (M = 3.92, SD = 0.26), indicating strong enthusiasm among students for hands-on learning. Similarly, students expressed high confidence in their experimental abilities following frequent laboratory activity, as shown in the mean score of 3.77 (SD

= 0.46) for the statement “I feel more confident in my ability to carry out experiment after participating in frequent laboratory practical activities in physics optics.”

Other statements also reflected students’ recognition of conceptual understanding and cognitive development fostered by frequent practical experiences. For instance, “I understand measurement error better due to frequent laboratory experience” had a mean of 3.47 (SD = 0.50), while “Frequent laboratory practice helps me make logical inference from data” recorded a mean of 3.40 (SD = 0.74). These responses suggest that students found laboratory experiences valuable for enhancing their scientific reasoning and analytical skills.

Technical skill acquisition was also perceived positively. The statements “I have improved my measuring skills through laboratory practical activities in physics optics” and “I am able to express my ideas and analyse situations very well after performing series of practical activities” both received identical mean scores of 3.36 (SD = 0.62 and SD = 0.89, respectively). These findings suggest that laboratory practice not only enhanced measurement accuracy but also improved students’ communication and analytical competence.

Further evidence of the effectiveness of frequent laboratory engagement is seen in the mean scores for motivation and interest-related items. The statement “Frequent laboratory practical activities have increased my interest in learning physics optics” had a mean score of 3.26 (SD = 0.70), while “Frequent laboratory practical activities have improved my ability to use scientific instruments” received similar mean score (SD = 0.44). These findings reinforce the motivational value of practical activities in engaging students with abstract physics concepts.

Although some statements received relatively lower mean scores, all were above the 2.5 midpoint, indicating general agreement. For example, ‘’I am more capable of modifying experimental procedures when needed due to my frequent laboratory practice” and “Frequent laboratory practical activities clarify the content taught through lecture in physics classroom received mean scores of 3.11 (SD = 0.72) and 2.81 (SD = 0.68), respectively. Even the latter, which was the lowest-rated item, still reflects general agreement that practical activity supports theoretical understanding. Similarly, the statement regarding increased curiosity through practical activities received a mean score of 2.87 (SD = 0.98), suggesting moderate support for the idea that frequent laboratory practical activity stimulates curiosity.

The overall mean score across all the 14 items was M = 3.22 (SD = 0.62), suggesting that, on average, almost all students had a positive perception of frequent laboratory practical activities in physics optics and perceived frequent laboratory practical activities in physics optics as beneficial in enhancing their science process skills acquisition, motivation, and understanding of content. These findings provide empirical support for the argument that hands-on laboratory experiences play a vital role in physics education, particularly in developing both procedural and conceptual competencies among students. For the example, Jeng, Chen and Kao (2021) revealed that students perceive laboratory practicals as highly beneficial for their learning, as they provide an opportunity to actively engage with scientific concepts rather than passively receive information from lectures. This active participation helps in making abstract theories in physics more relatable and comprehensible, which can boost students' enthusiasm for the subject. Jeng, Chen and Kao found that the excitement stems from the application of theoretical knowledge in real-world settings, which enhances their understanding and retention. Again, studies by Khalid and Aslam (2019) also found that laboratory practicals in physics and other science subjects provide a platform for both cognitive and emotional engagement. Students who participate in lab activities are more likely to feel a sense of accomplishment and excitement because they can directly observe the outcomes of their work. This not only strengthens their problem-solving abilities but also fosters a deeper emotional connection to the subject matter. Also, Issah (2021) revealed that students who participated in laboratory practical sessions developed a greater motivation to study physics and a more positive attitude toward the subject. Similarly, the finding in this current study buttresses the observation made by Akpan, Odu and Adebayo (2020) who highlighted that students who frequently engage in laboratory activities report higher levels of motivation to learn science. They argue that hands-on experiments in physics labs not only stimulate students' curiosity but also foster a positive attitude toward the subject. The excitement generated in such labs can shift the perception of physics from being a difficult and abstract subject to one that is more dynamic and engaging. The findings in this current study buttresses the conclusion by Tai, Sadler and Klahr (2020) that laboratory settings promote an active learning environment where students are not only recipients of information but are involved in constructing their knowledge. This active participation triggers a natural curiosity as students seek to understand how and why scientific principles work in real-life scenarios. Furthermore, Kim, Park and Lee (2021) found that students' curiosity and learning outcomes were significantly improved when practical experiments in physics directly related to real-world technological advancements. When students see the applicability of science, they are more likely to be curious about how science can solve real-world problems. Moreover, as revealed by Boud and Lee (2022) when students successfully complete experiments, they build confidence in their ability to engage with complex scientific tasks, leading to an increased desire to explore more. This positive reinforcement contributes to a self-sustained curiosity that encourages further learning and experimentation. The integration of frequent laboratory practical activities in science education plays a crucial role in fostering curiosity among students. These activities enhance engagement, critical thinking, and conceptual understanding, all of which contribute to a deeper curiosity about physics and science in general

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter presents a summary of the key findings of the study. It also outlines the conclusions drawn from these findings and offers recommendations based on the results. In addition, the chapter discusses the implications of the findings for the teaching and learning of physics.

5.1 Summary

The study was conducted as an action research project at Begoro Senior High School, Begoro, in the Eastern Region of Ghana. Its primary objective was to use frequent laboratory practical activities to enhance students' science process skills in physics optics. Science process skills encompass a set of cognitive and psychomotor abilities that are essential for conducting scientific investigations and developing a deep understanding of scientific concepts. Consequently, the study aimed to employ regular laboratory practical activities to strengthen students' acquisition of these critical skills.

In the course of the study, students participated in laboratory practical activities designed to facilitate the improvement of their science process skills. At the conclusion of each exercise, students completed laboratory practical tests based on the skills taught and practiced. The intervention strategies proved effective, as most students were able to provide correct solutions to the tasks presented. Analysis of data from both the weekly laboratory exercises and the post-intervention test indicated a positive improvement in students' acquisition of the required skills. Only a small number of students were unable to fully demonstrate the necessary skills during the intervention test.

However, students' performance in subsequent weekly exercises and the post-intervention assessments showed significant improvement compared to the results from the first week.

Furthermore, the null hypothesis, which stated that frequent laboratory practical activities have no significant effect on students' acquisition of science process skills, was rejected. These findings demonstrate that frequent, guided, and supervised laboratory practical activities substantially enhance students' competence in performing key science processes, including experimenting, observing, measuring, inferring, and communicating.

The study also found that the general perception of students towards frequent laboratory practical activities was inevitable in their physics lessons in optics. Students' responses revealed a consistent pattern of agreement across most items related to frequent laboratory practical activities and their role in acquiring science process skills. The mean scores for the majority of the items were above the 2.5 threshold, indicating a generally positive perception among students. Students reported that frequent exposure to hands-on laboratory tasks improved their ability to observe carefully; conduct measurements accurately, design and conduct experiments, make logical inferences, and effectively communicate their findings. Overall, the findings support the premise that frequent laboratory practicals contribute meaningfully to science education by fostering experiential learning and strengthening students' science process skills.

5.2 Conclusion

It is evident that the teaching and learning of physics are greatly enhanced through laboratory practical activities, as the subject cannot be effectively taught in the abstract. Students' understanding of physics concepts, principles, and laws appears to be closely linked to the number of practical experiences they engage in. Frequent laboratory practical activities are widely recognized in academic literature as an effective means of developing students' science process skills.

In relation to Research Question One, which aimed to determine the level of students' science process skills prior to exposure to frequent laboratory practical activities, the findings revealed that students initially demonstrated low proficiency. The pre-test results indicated that only a small proportion of students were able to correctly perform skills such as experimenting, measuring, observing, communicating, and inferring. This suggests that, before the intervention, students lacked sufficient practical competence in physics optics, particularly in applying theoretical knowledge to hands-on scientific investigations.

Regarding Research Question Two, which examined the extent of students' science process skills after exposure to frequent laboratory practical activities, the study found a significant improvement in all the assessed skills. The post-intervention results demonstrated a steady and progressive increase in the number of students who correctly acquired the targeted science process skills. Students showed remarkable improvement in experimenting, measuring, observing, communicating, and inferring skills, indicating that frequent and structured laboratory practical activities effectively enhanced their competence. The high post-test mean scores further confirmed that regular engagement in practical activity strengthens both cognitive and manipulative scientific abilities. Regarding Research Question Three, which examined the relationship between the frequency of laboratory practical activities and students' acquisition of science process skills, the study found a very strong positive correlation ($r = 0.987$). This indicates that as the frequency of laboratory practical activities increased, students' science process skills improved significantly. The results of the repeated measures ANOVA further confirmed that the observed improvement over the intervention period was statistically significant ($p < 0.001$), leading to the rejection of the null hypothesis. These findings demonstrate that frequent laboratory practical activities have a substantial positive impact on students' acquisition of science process skills in physics optics.

Furthermore, students' perceptions of frequent laboratory practical activities were overwhelmingly positive. An overall mean score of 3.22 suggested that students agreed that the activities enhanced their understanding, motivation, curiosity, confidence, and proficiency in using scientific instruments. This positive perception reinforces the effectiveness of frequent laboratory engagement as a strategy for improving science learning outcomes.

Overall, the findings indicate that laboratory practical activities positively influence students' acquisition of science process skills. Students who participated in frequent laboratory exercises showed noticeable improvement in these skills, confirming that the use of regular practical activities is an effective strategy for enhancing students' competence in science process skills.

5.3 Recommendations

The study after careful evaluation of the findings of the study and the conclusions has the following recommendations;

- Physics teachers in the Fanteakwa District are encouraged to prioritize the integration of practical activities into their daily classroom instruction, rather than limiting them to end-of-term or end-of-topic sessions. The findings of this study indicate that frequent hands-on laboratory activities significantly improve students' science process skills. Therefore, teachers should intentionally include simple, improvised, and curriculum-aligned practical exercises within regular physics lessons to reinforce the connection between theoretical concepts and practical application.
- Given the positive correlation established between frequent laboratory practical activities and the acquisition of science process skills, physics teachers within the

Fanteakwa District should increase the frequency of laboratory-based instruction. District-based subject meetings and professional learning communities should emphasize strategies for integrating practical activity into optics and other physics topics to improve students' experimenting, measuring, observing, inferring, and communicating skills.

- Since students demonstrated positive perceptions toward frequent laboratory practical activities, students in Senior High School in the Fanteakwa District should actively participate in practical sessions and make effective use of laboratory periods to enhance their science process skills. Students are also encouraged to handle laboratory equipment responsibly to ensure sustainability of resources.
- The administration of Senior High School Fanteakwa District should prioritize the maintenance and upgrading of the school's physics laboratory to support regular practical work. Adequate time should be allocated on the school timetable specifically for laboratory activities in physics to ensure that practical lessons are not rushed or omitted.
- The Ghana Education Service and relevant educational authorities should ensure that Senior High Schools within the Eastern Region are adequately equipped with functional physics laboratories and essential instructional materials. Additionally, periodic in-service training workshops should be organized for physics teachers to strengthen their competence in delivering frequent and effective laboratory-based instruction.

5.5 Suggestion for Further Studies

Since we are in educational reform era, there is room for further research on any aspect of the physics laboratory practical work at Senior High School level. It is therefore suggested that:

1. Future research could investigate the effect of frequent laboratory practical activities on the acquisition of science process skills in different aspect of physics
2. Researchers may explore whether there are significant gender differences in the way students acquire science process skills through laboratory activities.
3. Research could be carried out to identify challenges faced by students and teachers in organising frequent laboratory practicals.

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APPENDICES

APPENDX A

CHECKLIST FOR ASSESSING SCIENCE PROCESS SKILLS IN PHYSICS OPTICS PRACTICAL ACTIVITIES

Name of Supervisor……………………………………………………..
Week…………………….

Skills Area	Specific Indicators	CA	PA	NA
Experimenting	Selects appropriate optical instruments			
	Sets up the experiment according to the procedure with minimal guidance.			
	Identifies independent, dependent, and controlled variables correctly			
	Follows safety protocols			
	Adjusts apparatus to obtain clear and stable light rays or images			
	Uses appropriate methods to reduce systematic and random errors			
	Repeats trials to ensure consistency and reliability			
Measuring	Aligns instruments properly to avoid parallax errors			
	Uses protractors and rulers correctly to measure angles and lengths			
	Records measurements with appropriate significant figures			
	Identifies and corrects instrument zero errors.			
	Measures object/image distances			
Observing	Sketches ray diagrams accurately			
	Observes ray paths through different media			
	Observes refraction, reflection, and diffraction phenomena			
	Detects symmetry or distortions in ray paths or patterns			
	Notices changes as angle of incidence increases			

	Sketches ray diagrams accurately			
	Uses appropriate aids/tools to enhance observation			
Communicating	Draws and labels ray diagrams accurately			
	Presents data in well-organized tables			
	Constructs and labels graphs correctly			
	Follows proper lab report structure			
	Uses correct optics vocabulary			
Inferring	Derives physical laws from observed data			
	Predicts outcomes of changes in setup			
	Infers image properties from ray diagrams			
	Interprets graphs and relates slope/intercepts to physics concepts			
	Supports conclusions with data and theory			

APPENDIX B

QUESTIONNAIRE FOR RESPONDENTS

I am Festus Kofi Boni, an MPhil student of Science Education at the University of Education, Winneba carrying out a study on the title, the effects of frequent laboratory practical activities on the acquisition of science process skills of physics students in Presbyterian Senior High School, Begoro. Your feedback is very important, as your input will be used for academic purposes only. I greatly appreciate it if you could take a few minutes to provide me with information. Your response will be kept confidential and it will not be divulged to any person or institution outside this corporation.

Thanks in advance.

SECTION A: GENERAL INFORMATION ABOUT THE RESPONSES

Direction: Please respond to the options and kindly be guided by the scoring system below

Rating	Score Response	Description
1	Strongly disagree(S.D)	You agree with no doubt
2	Agree(A)	You agree with some doubt
3	Disagree(D)	You disagreed with some doubt
4	Strongly agree(S.A)	You disagree with no doubt

SECTION B: Students' perception toward frequent laboratory practical activities on the acquisition of science process skills.

Please, tick the option that best reflect how you associate with each of the following statements.

Statement	**S.A**	**A**	**D**	**S.D**
Frequent laboratory practical activities have helped me develop my observing skill				
I have improved my measuring skills through laboratory practical activities in physics optics				
I feel more confident in my ability to carry out experiment after participating in frequent laboratory practical activities physics optics				

I have improved my communication skills through frequent laboratory practical activities in physics optics				
Frequent laboratory practical activities have increased my interest in learning physics optics				
Frequent laboratory practical activities have improved my curiosity in learning of physics optics				
Frequent laboratory practical activities have improved my motivation in learning of physics optics				
I get excited whenever we perform practicals and I wish we do practicals every day during physics lessons				
Frequent laboratory practical activities clarify the content taught through lecture in physics classroom				
Frequent laboratory practical activities have helped me develop my critical thinking skills				
Frequent laboratory practice helps me make logical inference from data				
I am able to express my ideas and analyse situations very well after performing series of practical activities				
I understand measurement error better due to frequent laboratory experience				
Frequent laboratory practical activities have improved my ability to use scientific instrument				

APPENDIX C

SMAPLE OF THE LESSON PLAN

LESSON ONE

Week ending: 8/08/2024	**Duration:** 110 minutes	**Subject:** Physics
Day: Tuesday	**Class**: SHS 2	**Topic:** Light
Time: (9:25 – 10:25 am)	**Class size:** 53	**Sub-topic**:
Reference: Paul A. ((2020). *Physics for Senior High Schools.* Atta Kay Publications Company Limited. Amoako, C & Asiedu, P (2008). *Physics for Senior High School*. Aki Ola Publications Company Limited. Ghana Education Service(2019). *Physics Syllabus for Senior High Schools*. Ministry of Education		

Objective/RPK	**Teacher Activities**	Learner activities	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
Objective	**Introduction**				**Evaluation**
By the end of the lesson, students will be able to:	Teacher asks questions to review prior knowledge. Students respond orally.		Whiteboard, marker, videos,	Light travels in straight lines (Rectilinear propagation).	Oral questioning
1. Identify laboratory equipment used in optics and state their functions.	**Activity 1** Teacher displays apparatus for the lesson.	Students identify apparatus displayed and state their functions.	Optical pins, glass block, prism, protractor, mirrors etc		

2. Describe what happens when light passes through glass block and prism and state the phenomenon observed 3. Read scales correctly. 4. Draw angles accurately.	Teacher asks students to observe how bend through glass block prism	Students observe light passing through glass block and prism. Students measure given angles.		Refraction is bending of light when it passes from one medium to another.	**Evaluation** 1. Define the term refraction. 2. Draw the following angles. 45°, 60° 3. State the function of glass block prism.
	Teacher guides students to measure given angles	Students measures some angles	Protractor, ruler, pencil	Correct positioning of protractor. Accurate angle measurement	
	Teacher guides students to draw given angles using their protractors	Students use protractor to draw angles such as 30°, 40°, 50°.	Protractor, ruler, pencil	**Application** Students explain why a spoon appears bent in water. Identify examples of refraction (rainbow, swimming pool).	
	.				
	GESI Consideration Equal participation of boys and girls. Mixed ability grouping. Support for visually challenged students	Inclusive grouping	Teamwork & accountability.	Promotes equal learning opportunity	
	SELL Integration				

RPK Students already know that light travels in straight lines. Basic measurement of angles.	**Closure** Teacher summarizes lesson. Students ask questions	Group collaboration. Leadership roles assigned. Careful handling of apparatus builds responsibility.			Observation of participation **Remarks** Lesson was successfully taught.

LESSON TWO

Week ending: 15/08/2024	**Duration:** 110 minutes	**Subject:** Physics
Day: Tuesday	**Class**: SHS 2	**Topic:** Light
Time: (9:25 – 10:25 am)	**Class size:** 53	**Sub-topic**:
Reference: Paul A. ((2020). *Physics for Senior High Schools.* Atta Kay Publications Company Limited. Amoako, C & Asiedu, P (2008). *Physics for Senior High School*. Aki Ola Publications Company Limited. Ghana Education Service(2019). *Physics Syllabus for Senior High Schools*. Ministry of Education		

Objective/RPK	**Teacher Activities**	Learner activities	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
Objective By the end of the lesson, students will be able to: 1. Trace the outline of a glass block correctly. 2. Draw normal and angle of incidence. 3. Measure angle of refraction.	**Introduction** Teacher reviews definition of refraction and sine ratio. **Activity 1** Teacher demonstrates tracing the glass block and drawing the normal. Teacher guides students to place rectangular glass block on paper and trace the outline	Students observe how to trace the outline of glass prism and the drawing of normal	Whiteboard, marker, videos, Glass block, prism, protractor, etc	The normal is drawn at 90° to surface.	**Evaluation** Oral questioning

4. Calculate sin i and sin r. 5. Verify Snell's Law. **RPK** Students already know that light travels in straight lines and the	Teacher guides students to draw the normal Teacher guides students to use their protractor to draw incident ray at i = 30° Teacher guides students to trace the image of the pins observed in the prism .	Students trace the outline of the given prism Students mark point B and draw normal. Students use their protractors to draw incident ray at i = 30°. Students replace their block and fix pins P1 & P2 on the incident ray Students fix P3 & P4 in line with images observed in the prism. They remove the block and join the points They measure the angle of refraction r. Students calculate sin i and sin r.	Protractor, ruler, pencil Protractor, ruler, pencil Glass prism, pencil, ruler Optical pins, prism, pencil Calculators Protractor, ruler, pencil**,**	Light bends towards the normal when entering glass. Correct positioning of protractor. Accurate angle measurement Snell's law: sin i / sin r = constant. • The constant is refractive index (n). **Application** Students determine refractive index from their table.	**Evaluation** State Snell's law

meaning of angle of incidence. They also know how to use protractor.	GESI Consideration Equal participation of boys and girls. Mixed ability grouping. Support for visually challenged students SELL Integration **Closure** Teacher summarizes that ratio sin i/sin r is constant.	Students repeat the process for 35°, 40°, 45°, 50°. In case, students calculate sin i and sin r. Inclusive grouping Group collaboration. Leadership roles assigned. Careful handling of apparatus builds responsibility.	glass prism, pencil, ruler Calculators	Promotes equal learning opportunity Teamwork & accountability.	**Remarks :** Lesson was successfully taught.

LESSON THREE

Week ending: 22/08/2024	**Duration:** 110 minutes	**Subject:** Physics
Day: Tuesday	**Class**: SHS 2	**Topic:** Light
Time: (9:25 – 10:25 am)	**Class size:** 53	**Sub-topic**:
Reference: Paul A. ((2020). *Physics for Senior High Schools.* Atta Kay Publications Company Limited. Amoako, C & Asiedu, P (2008). *Physics for Senior High School*. Aki Ola Publications Company Limited. Ghana Education Service(2019). *Physics Syllabus for Senior High Schools*. Ministry of Education		

Objective/RPK	**Teacher Activities**	Learner activities	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
Objectives By the end of the lesson, students should be able to: 1. Draw a graph of sini against sinr 2. Find the slope of the graph	**Introduction** Teacher reviews definition of refraction and sine ratio. Teacher also reviews tracing of the outline of the glass block and drawing of the normal with learners **Activity 1**	Students observe attentively	Whiteboard, marker, videos,	The normal is drawn at 90° to surface.	**Evaluation** Oral questioning

3. State the significance of the slope.	Teacher guides students to trace, measure and record given the values of i and r using the rectangular prism	Students trace the outline of glass prism and the normal, incident ray at given values of i and measure and record the values of r	Glass block, prism, protractor, etc		
RPK: Students already know refraction of light	Teacher guides to draw table of values indicating i, r, sini and sinr	Students draw table of values indicating i, r, sini and sinr	Calculator		**Evaluation** Explain what is meant by refractive index of a medium is 1.33
	Teacher guides students to draw the vertical and the horizontal axes and label it	Students draw the vertical and the horizontal axes and label at sini and sinr respectively	Graph sheet, ruler, pencil		
	Teacher guides students to choose the appropriate scale	Students choose appropriate scale for the graph			
	Teacher guides students to plot the values of sini against sinr .	Students plot the values of sini against sinr	pencil	**Application** Students determine refractive index from their table. Refractive index of a medium measures how much light slows down and	
	Teacher guides students to determine the slope of the graph	Students draw triangle and use it to determine the slope of the graph	ruler and pencil		
	Teacher guides students to identify the significant of the slope				

	GESI Consideration Equal participation of boys and girls. Mixed ability grouping. Support for visually challenged students SELL Integration **Closure** Teacher summarizes that slope represents the refractive index of the glass prism is constant.	Students state that the slope represents the refractive index of the prism. Inclusive grouping Group collaboration. Leadership roles assigned. Careful handling of apparatus builds responsibility.		bends when it passes from one medium to another. Promotes equal learning opportunity Teamwork & accountability.	**Remarks :** Lesson was successfully taught.