GUIDED AND OPEN INQUIRY-BASED LEARNING APPROACHES ON STUDENTS' ACADEMIC ACHIEVEMENT IN PHYSICS IN SECONDARY SCHOOLS IN SUBA SOUTH SUB-COUNTY, KENYA

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Education of Murang'a University of Technology

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DECLARATION

Student Declaration

I hereby declare that this thesis is my original work and, to the best of my knowledge, has not been presented with a degree award at this university or any other university. I understand what plagiarism is and I am aware of the university's policy in this. I understand that any false claim regarding this work shall result in disciplinary action in accordance with the University Anti-Plagiarism Policy.

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Supervisors' Approval

The undersigned certify that they have read and hereby recommend for acceptance of Murang'a University of Technology a thesis entitled **"Guided and Open Inquiry-Based Learning Approaches on Students' Academic Achievement in Physics in Secondary Schools in Suba South Sub-County, Kenya".**

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DEDICATION

I dedicate this work to Juliet Akoth for her continued concern and exhortation to continue with the work, however tiresome it may feel at times. To my father, Charles Sabutha, for planting the germ of this study in me at a very tender age.

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ABSTRACT

Physics as a science is so crucial for technological advancement and innovation in the 21st century. It helps students understand how the concepts of matter and energy are related under the fields of mechanics, electricity and magnetism, waves, optics, and thermodynamics. Despite the significance of physics in innovations and advancements in technology, its enrollment and performance in secondary schools and tertiary levels have been alarming. Students have consistently recorded low achievements in external tests such as the KCSE. This low achievement has been linked to conventional teaching methods, which are examination-oriented and teacher-centered. As a result, educational policies have resolved on learner-centered instructional strategies such as Inquiry-Based Learning. Several studies that have focused on Inquiry-Based Learning (IBL) have shown that it influences students' academic achievements positively, especially in STEM disciplines. However, as far as the literature search for the current study was done, limited studies in Kenya addressed the effect of guided and open approaches to IBL on students' achievement in Physics. This study, therefore, embarked on investigating the effect of guided and open approaches to inquiry on students' achievement in Physics among students in Kenyan public schools. Constructivist and constructionism learning theories guided the study. The specific objectives of this study were: to investigate the effect of guided and open inquiry on students' performance in physics projects, to investigate the effects guided and open inquiry have on students' physics achievement scores, to determine the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and project performance, and to explore the challenges secondary school teachers face in the implementation of IBL. The study adopted convergent parallel mixed methods research, where Solomon's Four quasi-experimental design was used to collect the quantitative data, while questionnaires were used to collect qualitative data. The target population for the study was 3312 form three students enrolled in the public secondary schools in the subcounty, together with 637 teachers in the schools. Purposive, stratified, and simple random sampling techniques along with Cochran's formula, were used to sample 345 students to represent the target population. A total of 176 students and 6 teachers became the respondents who took part in the study. Analytic rubric, physics achievement test, and teachers' questionnaire were the data collection instruments that were used for data collection. Descriptive statistics, including mean, standard deviations, and frequencies, were used to describe the nature of the students' responses. Inferential statistics that included independent sample t-tests, paired sample statistics, Wilcoxon Signed-Rank, Mann-Whitney U-test and ANCOVA were used to draw conclusions of the study. SPSS version 25 was used to aid the analysis process. All the hypotheses were tested at a significance level of 0.05. The results showed that both guided and open approaches to inquiry had an improvement effect on both students' physics achievement scores and project performance, though guided inquiry proved to be a stronger predictor to the achievement scores and the project performance than open inquiry did. In addition, the outstanding challenge teachers agreed upon were poor internet connectivity and the digital divide. The researcher recommended the adoption of IBL for secondary physics instruction.

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ACRONYMS AND ABBREVIATIONS

5E	Five-phase instructional model: Engage, Explore, Explain, Elaborate, Evaluate
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BSCS	Biological Sciences Curriculum Study
BSPSAT	Biology Science Process Skills Achievement Test
CBE	Competency-Based Education
CFAT	Carnegie Foundation for the Advancement of Teaching
CLASS	Colorado Learning Attitudes about Science Survey
CRT	Criterion Referenced Physics Test
E1, E2, C1, C2	Experimental and Control groups (Solomon's four design)
FCI	Force Concept Inventory
GIS	Geographic Information Systems
IBL	Inquiry-Based Learning
IBSE	Inquiry-Based Science Education
ICT	Information and Communication Technology
IEBC	Independent Electoral and Boundaries Commission
ISERC	Institutional Scientific and Ethics Research Committee
KCSE	Kenya Certificate of Secondary Education
KICD	Kenya Institute of Curriculum Development
KNEC	Kenya National Examinations Council
NACOSTI	National Commission for Science, Technology, and Innovation
O1, O2, O3, O4, O5, O6	Observations at different test phases (Solomon's design notation)
PAT	Physics Achievement Test
PSS	Public Secondary School (1, 2, 3,…)
SPSS	Statistical Package for the Social Sciences
SS1, SS2	Senior Secondary 1, Senior Secondary 2 (Nigeria context)
STEM	Science, Technology, Engineering, and Mathematics
TBE	Traditional-Based Experim
T1	First teacher
T2	Second teacher
T3	Third teacher
T4	Fourth teacher
T5	Fifth teacher
T6	Sixth teacher

OPERATIONAL DEFINITION OF TERMS

Inquiry-based learning: this is a strategy of learning that enables the building of knowledge and understanding through discovery. It gives students autonomy in taking responsibility for their learning process, and teachers become facilitators who provide favorable environments for inquiry.

Open inquiry: the least structured form of inquiry-based learning, in which learners are neither given a research question nor procedures for solutions. Students develop the research topic and procedures independently, conduct the inquiry, and provide findings.

Guided inquiry: an approach to IBL where learners are provided with research questions, but left to independently develop the procedures for their solutions, conduct the inquiry, and present the findings.

Analytical rubric: a type of rubric that provides detailed descriptions of certain assessment criteria, alongside measurement scales in each criterion. It will be developed and used to assess the students' performance in the project.

Physics performance: level of learning attained that is judged by hands-on activities, which leads to the creation of tangible artifacts. The design of projects in refraction of light will show this achievement.

Achievement scores: quantitative outcomes of an evaluation that show students' level of knowledge and skills attainment in a subject or grade level after a period of learning, usually measured by a written test. It will be determined by administering pre- and post-Physics Achievement Tests.

CHAPTER ONE
INTRODUCTION

1.1 Background to the study

Physics education is so crucial in the curriculum at both secondary and tertiary levels, as it gives students a better understanding of the natural world and enhances their critical thinking skills (Abdulmalik Olayinka Anwo et al., 2025). As a branch of science, physics enlightens students about the concepts of how matter relates to energy in fields such as mechanics, sound, heat, light, electricity, and the atomic nucleus, enabling students to understand what happens in our world and why it happens (Young and Freedman, 2020). However, evidence suggests that students struggle with abstract physics concepts, resulting in low physics achievement. Data from the KNEC portal indicate that physics scores in Kenya have consistently been below a 40% average, as shown in Table 1.1

Table 1. 1: Students' KCSE physics achievement since 2020-2024

Year	paper	Maximum score	Mean score per paper	Overall mean score
2020	1	80	32.49	39.77
	2	80	29.91	
	3	40	17.15	
2021	1	80	24.57	35.04
	2	80	26.22	
	3	40	19.33	
2022	1	80	22.98	34.27
	2	80	22.13	
	3	40	19.43	
2023	1	80	25.63	32.59
	2	80	20.43	
	3	40	19.13	
2024	1	80	21.58	35.52
	2	80	25.93	
	3	40	23.55	

Source: Teacher.co.ke (2024)

According to Owadara (2022), traditional teacher-centered methods offered students very minimal opportunity to enhance their curiosity and critical thinking skills, thereby calling for a transfer from the teacher-centered methods emphasizing on textbooks, lectures and scientific, to inquiry-based approaches that captures and sustains students' interest in science, allowing students to use logic and empirical evidence to solve problems, and encouraging students to conduct further studies to develop deep understanding of concepts and writing of scientific explanations backed

up with clear empirical evidence (Nnadi, 2022). As a result, educational practices worldwide have continuously shifted from teacher-centered to learner-centered instructional methods. This change is especially noticeable in STEM disciplines, where teacher-centered instruction has been associated with a lack of engagement and lower performance (Waked et al., 2024). Among the learner-centered teaching approaches that have gained global recognition for enhancing students' performance and their success in academic work is inquiry-based learning (Gorbunova et al., 2023).

IBL is an approach to instruction in which students discover knowledge by themselves instead of passively receiving it from instructors. It is a science teaching approach that makes it possible for students to replicate scientists' search for solutions through inquiry (Dmoshinskaia et al., 2021). The 5E model of instruction, formulated by the Biological Sciences Curriculum Study (BSCS) in 1987 guide the IBL sessions. The 5E was derived from the first letters of the five words of the model, which are engage, explore, explain, elaborate, and evaluate, in the order from the first to the last (Thangjai & Worapun, 2022)

IBL generally involves several levels, classified by how much guidance teachers provide. From the most to the least structured, they are confirmatory, structured, guided, and open inquiry. Guided inquiry occurs when the instructor formulates the research question and provides it to students, who then design procedures to address the problem. Conversely, in open inquiry, the teacher supplies only the background information surrounding the research topic, leaving students to formulate the research question and the procedures to find a solution (Bansiong, 2023). However, determining the most appropriate level to implement in the classroom remains a contentious issue. Some educators advocate for more structured levels with high teacher guidance to reduce cognitive load on students' working memory (Ulmanen et al., 2023). In contrast, others support less structured levels with minimal teacher involvement to promote student independence (Ulmanen et al., 2023). Striking a balance where students are autonomous yet adequately guided continues to be a significant challenge.

IBL has been recognized globally for its ability to enhance students' academic achievement. The Carnegie Foundation for the Advancement of Teaching (CFAT) acknowledged the importance of incorporating inquiry elements into the 2010

curriculum reform of Medical Education in America to boost knowledge acquisition skills (Verma et al., 2023). A meta-analysis conducted in the United States showed generally positive perceptions among trainees regarding IBL (Verma et al., 2023). When comparing the effectiveness of open and guided approaches to inquiry, American researchers report results that favor open inquiry (Cai et al., 2021). They argue that students in guided inquiry mainly adhere to the provided procedures to finish the problem, while those in open inquiry explore a range of alternatives, which enhances their critical and creative thinking. However, the results basically relied on the subjective response from students, without the use of validated tools that give objective feedback. This may raise concerns about the validity of the results, considering the changing nature of learners' perceptions towards different approaches to instruction, and necessitates the need for similar research, but with validated tools for more reliable and valid findings.

Majority of official academic documents and science education literature in Europe emphasize the inclusion of Inquiry-Based Science Education (IBSE) (Strat et al., 2024). Education policymakers in Europe claim that IBSE aligns with how students learn science, enhances students' interest in learning science, and improves learning outcomes, especially when students develop, present, and discuss their explanations in class. However, given the various approaches IBL can be conducted, European researchers have not specified which IBL approaches can maximize the benefits they mention. One European research project focused solely on investigating how guided inquiry was carried out in school chemistry classes. Orosz et al. (2023) reported that guided inquiry effectively develops practical skills, as learners were observed to set up the apparatus meaningfully and follow safety procedures, despite not being provided with manuals. Since this study concentrated on just one approach to inquiry, it is not reasonable to dismiss the effectiveness of other approaches without further investigation.

During instructional reforms, Asia shifted toward an inquiry-based curriculum at all levels: elementary, secondary, and tertiary. Asian researchers believe that, because of its constructivist nature, IBL encourages higher-order thinking skills by engaging students in collecting evidence, scrutinizing explanations, considering alternatives, and organizing findings (Antonio & Prudente, 2024). One of the studies advocated for

guided inquiry, claiming that it allows appropriate scaffolding while still giving learners autonomy and responsibility over their work (Antonio & Prudente, 2024). A separate study in Indonesia revealed results that supported open inquiry over guided and structured inquiries (Artayasa et al., 2018). Proponents of open inquiry claimed that the amount of effort students employed in searching literature and formulating their questions and procedures gave them ample time to grasp the concepts better.

Several West African countries recognize the importance of IBL in enhancing performance in STEM subjects, but effective implementation remains difficult due to inadequate teacher training and uncertainty about which inquiry level suits secondary school students best (Assuah et al., 2022). For instance, countries like Ghana and Nigeria still primarily conduct confirmatory inquiries, where students follow prescribed procedures to verify laws provided to them.

South Africa, having reformed its curriculum to make instruction more learner-centered, has adopted IBL in STEM fields, but evidence indicates that its implementation has been inconsistent (Nkosi & Motlhabane, 2025). Some studies suggest that IBL did not produce the expected positive outcomes. Other countries in Southern Africa, such as Zimbabwe, are leading reforms emphasizing IBL; however, implementation faces numerous challenges, including a lack of understanding among teachers about how to properly execute IBL (Mrosso et al., 2025). Conventional lecture-based instruction still dominates in classrooms and laboratories, with students often following manuals strictly. In places like the Democratic Republic of Congo, some efforts to introduce IBL in these settings have elicited mixed reactions; while some support its use, others doubt its effectiveness (Mrosso et al., 2025). Since many researchers have documented the benefits of IBL, these mixed reactions may stem from adopting ineffective inquiry approaches that undermine its potential, whereas proper implementation of an appropriate approach could yield better outcomes. Therefore, identifying the most suitable inquiry level for secondary schools remains an underexplored area that warrants further study.

Mbata et al (2025), in their non-equivalent quasi-experimental research in Tanzania, provide results that embrace guided inquiry over all the other approaches to inquiry. They argue that confirmatory and structured approaches to inquiry are very structured, and linked them to traditional-based experiments (TBE). They also criticized open

inquiry for being too abstract and difficult to translate into classrooms, especially among novice students, and in a mixed classroom environment, with students of varied abilities. Guided inquiry, according to these researchers, gives students a chance in their learning process while still receiving a little support from the instructor.

The effectiveness of IBL has been experimentally validated in Kenya by many researchers (Nzomo et al., 2023). Kunga (2021) conducted a quasi-experiment in Kitui County to verify this claim. Due to the documented effectiveness of IBL, it has been recommended by the Kenya Institute of Curriculum Development (KICD) for classroom and laboratory instruction under the new Competency-Based Education (CBE). However, KICD has recommended IBL without giving clarifications on how best it can be adopted in the classroom setups, given the varied approaches to inquiry and constraints that come with its adoption.

From the foregoing, it is evident that researchers globally have presented the effectiveness of IBL, but haven't resolved on the best approach to conduct IBL, considering the autonomous nature of inquiry and the need for teachers' guidance in the process of inquiry. The constraints of time and resources worsen the situation. Therefore, the current study aims to provide empirical evidence to support the selection of a given approach to inquiry, between guided and open, while considering all the constraints of time and resources.

1.2 Statement of the problem

Following the adoption of competency-based education (CBE) in Kenya, the KICD has advocated for instructional approaches to learning that are inquiry-based, game-based, project-based, and flipped classes, which centre around learners rather than teachers. However, educational policies have promoted these transformations without providing clear pedagogical guidelines. For instance, IBL has been promoted without clearly defining the extent of teacher involvement, which determines the level of inquiry adopted. The trend of poor content grasping in practical subjects like Physics has continued, which translates to low performance in both internal and external physics examinations, despite the reformations made in instructional approaches (KNEC, 2017-2022; Kunga, 2021). Studies on the optimal ways of implementing

these proposed instructional strategies, IBL being one of them, can help boost performance in the STEM disciplines.

Furthermore, studies in Kenya and beyond its borders on the relevance of IBL in enhancing conceptual understanding among STEM students have revealed inconsistent findings. Wang et al (2022) call for researchers to take a close look at which approach to IBL contributes more positive results on the students' achievements in STEM disciplines. This, they argue, will address the ongoing debate on which level of inquiry is the most appropriate for students in secondary schools, considering the resource, time, and learning experiences limitations that exist in the classrooms.
Therefore, the current study seeks to find out the effectiveness of guided and open inquiry, and further determine which one leads to better content grasping in physics, which will translate to high physics achievement and improved enrollment. Additionally, the current study will address the inconsistent findings regarding which of the two, guided and open inquiry, leads to greater physics achievement.

1.3 Objectives of the study

1.3.1 General Objective

The main aim of this study was to determine the comparative effect of guided and open inquiry on students' physics achievement scores and project performance.

1.3.2 Specific Objectives

i. To investigate the effect of guided and open inquiry on students' performance in physics projects in Suba South Sub-County.
ii. To investigate the effect of guided and open inquiry on students' physics achievement scores.
iii. To determine the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and project performance.
iv. To explore the challenges that secondary school teachers face in the implementation of IBL in physics instruction.

1.4 Research hypotheses

HO_1: Guided inquiry has no statistically significant effect on students' performance in physics projects in Suba South Sub-County.

HO_2: Open inquiry has no statistically significant effect on students' performance in physics projects

HO_3: Guided inquiry has no statistically significant effect on students' physics achievement scores.

HO_4: Open inquiry has no statistically significant effect on students' physics achievement scores

HO_5: There is no statistically significant difference in the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and project performance.

HO_6: There is no statistically significant difference in the comparative effect of guided and open inquiry in enhancing students' physics project performance.

1.5 Research question

What challenges do teachers face in their attempt to implement IBL in physics instruction?

1.6 Justification of the study

Inquiry-based learning approaches are pivotal in learning science for they engage learners in solving authentic problems in the learning setting, unlike conventional learning methods, which lead to rote memorization (Furtak et al., 2022). However, several researches have shown that the effectiveness of the IBL in enhancing conceptual understanding and general students' academic achievement strongly depends on the extent of teachers' support, which in turn determines the approach of inquiry adopted: very minimal teacher assistance which is equivalent to open inquiry is criticized for increasing extraneous cognitive load in students' working memory, especially the novice learners, while too much teacher guidance is also denounced for denying students' autonomy in taking responsibility over their work (de Jong et al.,

2023). Thus, determining how guided versus open inquiry influences physics achievement, considering the demands of the cognitive load theory requiring guided instruction and those of constructivists' learning theorists who advocate for students' autonomy over their work remains a pressing empirical question with direct implications for learning settings.

In Kenya, the education policy makers have endorsed learner-centered, inquiry-oriented instruction approaches through the newly adopted Competency-Based Education, with very limited implementation guidance about teachers' roles and the extent of scaffolding learning appropriate under learner-centered approaches (Nzomo et al., 2023). The continued reports of low physics performance in the national exams (KNEC Report, 2017-2022) indicate a gap between policy and practice. The curriculum promotes inquiry, but the teachers lack locally generated evidence on what approaches are typical of science classes. In addition to the lack of such guidelines from the curriculum developers on the extent of teacher guidance, no study has addressed the reliability of guided and open inquiry in enhancing students' academic achievement. Nzomo et al (2023) call on researchers to investigate how the different approaches to inquiry relate to students' academic achievement. This study, therefore, seeks to address the call from earlier researchers by investigating how guided and open inquiry affects students' achievement in physics.

1.7 Significance of the study

This study has multifaceted significance, impacting several stakeholders participating in the field of education, comprising students, teachers, educational policy makers, and researchers.

The study has the potential to improve concept grasping among students. Concept grasping in abstract STEM disciplines like physics has been very low, as reflected in the consistent records of low performance both at school-based and national levels (KNEC Reports, 2017-2022). By identifying an optimal approach to IBL, this study may help enlighten students on the best approach to adopt when doing IBL, which may maximize conceptual understanding and enhance performance in physics. Consequently, students' attitudes towards physics may change positively, resulting in increased enrollment in physics.

The study provides important insights to instructors and teachers on the effective instructional approaches in IBL classes. By linking constructivist learning theories which emphasize on students' active role in building their knowledge, and the principles of limited working memory which advocates for adequate teacher guidance in classes to minimize extraneous cognitive load in students' working memory, teachers may be able to settle on optimal approach to IBL, which allows their involvement in students learning, while still giving the learners a considerable autonomy over their work.

For bodies responsible for developing curriculum, particularly the Kenya Institute of Curriculum Development (KICD) and formulating educational policies, the study provides a useful empirical information which can be used as the basis for developing IBL implementation framework. The findings may also inform the training of both novice and in-service teachers on how to navigate the complexities of IBL which presents the disconnect between the curriculum specifications and the realities in the IBL classes.

The study also contributes to the growing academic and research community by adding localized research to the expanding body of scholarly publications. Though several studies have documented findings on research on IBL, most have been done either at the regional or national levels. For the generalizability of the effectiveness of certain approaches to IBL, then the empirical data supporting the same must be documented across several cultures, and from grassroots to national levels. This study, therefore, provides evidence from the grassroots level, which can influence more equitable educational reforms and policies.

Finally, this study may add a significant impact on the continued efforts to modernize STEM education globally. Due to the global quest for technological advancement and innovation, every nation is striving to revive its STEM disciplines. As Kenya also strives to align its STEM education to international standards, this study may provide insights into how the performance and enrollment in these disciplines can be maximized. This may be made possible through the provision of frameworks that inform dynamic STEM instruction and curriculum designs.

1.8 Scope of the study

The study was conducted in Suba South, which is one of the eight sub-counties in Homa Bay County. The target population was the Form Three students in the 39 public senior secondary schools within the sub-county. According to Solomon's four research designs, the sample size was 351 physics students enrolled in four purposively selected secondary schools. The sample schools included two mixed-gender schools, one boys' school, and one girls' school. This approach maintained gender and institutional diversity. Public secondary schools were chosen for this study because of their convenience for conducting research, unlike private schools, which often impose restrictions on external research. In addition, they also offer a standardized curriculum.

The cognitive maturity of Form Three students made them suitable participants for this study, as they could engage meaningfully with IBL tasks while still having adequate exposure to physics before terminal examinations. The findings were used to probe the effectiveness of IBL to the entire student population in Suba South Sub-County, with implications for physics instruction in similar rural and peri-urban contexts in Kenya. The persistent challenges in physics achievement, where KNEC records reports lower-than-average performance in science subjects compared to other subjects justified the selection of Suba Sub-County for the study (KNEC, 2022). Evidence shows that context-specific interventions in science pedagogy can dictate frameworks for replication in other contexts, as IBL approaches tested in one locale often yield transferrable strategies across diverse educational settings (Furtak et al., 2022). Therefore, although the findings were generated from Suba South Sub-County, they have relevance and replicability beyond the immediate locale.

1.9 Limitations of the study

This study was limited to Form Three students in public secondary schools in Suba South Sub-County. This could affect the extent to which the study findings could be inferred to other students in the sub-county, including those in private schools, primary, and tertiary levels. In addition, although Solomon’s Four-Group Design is capable of reducing certain threats to the validity of the study findings, exercising control over all intervening variables such as prior exposure to other inquiry-based approaches, and access to external assistance from more experienced peers may not be fully achievable. Particularly, it was challenging to ensure that the open inquiry

students do not get unintended assistance from either the teacher or more experienced peers, which could compromise treatment fidelity.

The purposive sampling of four public secondary schools out of the 39 could limit the representativeness of the sample size, undermining the external validity of the study outcomes. Such limitations are often encountered in social sciences like educational setups in which the contextual realities restrain randomization and broader sampling (Creswell & Creswell, 2021). Despite the few limitations, the research design is suitable for social sciences and is recommended for instructional interventions where controlled randomization is not possible (Creswell & Creswell, 2021), and so the study was expected to provide valuable insights.

1.10 Delimitation of the study

This study was delimited to Form Three Physics students and their respective teachers in public secondary schools within Suba South sub-county, Homa Bay County. Other grade levels and subject teachers other than physics were not included, as the researcher sought to determine the effectiveness of IBL in relation to Physics. Only public secondary schools were considered because they offer a standardized basis for comparison, unlike private schools, which sometimes differ in terms of their curriculum design and pedagogical frameworks.

Among all science subjects that can be taught using inquiry methods, the study was delimited to Physics for its continued alarming performance in national exams and low enrollment over the past decades (KNEC Report, 2017-2022), warranting targeted pedagogical interventions. Additionally, the study was delimited to two levels of inquiry in IBL: guided and open. This maintained a manageable scope and enabled a clearer comparison. Achievement assessment primarily relied on written tests and project performance. While this may not capture other learning gains, such as critical thinking, it provided valid and measurable indicators of academic achievement. Finally, the study was restricted to past KCSE physics questions related to refraction of light.

1.11 Assumptions of the study

The study assumed the following;

i. The students and teachers sampled were a good representation of the entire population, and the findings were sensible if inferred to the entire population.
ii. All the students sampled had relatively similar prior knowledge in the topic of discussion, and any difference that was observed in the tests after interventions were as a result of the interventions.
iii. That Physics Achievement Test and the analytic rubric were valid and reliable tools for assessing conceptual understanding and physics performance.
iv. Teachers implemented the inquiry classes exactly as they were inducted for both guided and open inquiry.
v. The students were cognitively mature enough to participate in the study.

1.12 Contributions of the Thesis

This thesis makes significant contributions to educational policymakers, instructors, and students. The thesis provides useful information to education policymakers for developing an IBL implementation framework and for informing the training of instructors on the optimal ways to implement IBL in classrooms. The thesis also links students' working memories to the complexities of IBL, thereby informing instructors on how to take both dimensions into account during classroom instruction. For students, the thesis provides background information on the four approaches to inquiry and the best approach to adopt when conducting inquiries. By adopting the optimal approaches to inquiry as presented in this thesis, students' conceptual understanding and physics performance are likely to improve. The thesis also contributes to ongoing research and the global effort to modernize STEM education. Every nation is striving to enhance STEM education; therefore, this thesis continues that effort by providing the literature to advance the process.

1.13 Organization of the Thesis

This thesis is organized into five chapters as follows: Chapter one entails the background to the study, statement of the problem, objectives of the study, research hypotheses, research questions, justification of the study, significance of the study, scope of the study, limitations of the study, delimitation of the study, assumptions of the study, and the contributions of the study. Chapter two describes the theoretical framework, the conceptual framework, and the empirical review of as per the specific

objectives of the study. Chapter three addresses the research methodology, including the research philosophy, research design, locale of the study, target population, sampling, data collection instruments, validity, reliability, pilot study, data collection procedures, data presentation and analysis, logistics and ethical considerations. Chapter four presents the study results and discussion, including interpretations and implications of the findings. Chapter five presents the summary of the findings, conclusions and the recommendations of the study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter comprises the theoretical framework, the conceptual framework, and the empirical review. The empirical review was conducted according to the themes of the objectives.

2.2 Theoretical Framework

This study was based on two theories: constructivist learning theory and the constructionist learning theory. The discovery nature of IBL, where learners construct knowledge on their own and do not passively receive it from the instructors, made the two theories based on discovery suitable for the study.

2.2.1 Constructivist Learning Theory (Piaget, 1964)

In an IBL classroom, learners actively construct knowledge through discovery and exploring different resources, rather than passively absorbing it from instructors (Mrosso et al., 2025). Cognitive constructivists agree with the above notion of how students learn by posing that learners build their understanding and knowledge based on their past experiences (Piaget, 1964). Advocates of Constructivist Learning Theory agree with the proponents of IBL when they claim that learners are not empty slates when they enter classrooms but rather bring numerous prior experiences, which they reflect on and use to build new knowledge (Mrosso et al., 2025). Therefore, when learners encounter new experiences, they may adjust their existing schemas to accommodate the new information, integrate the new knowledge with existing understanding, or discard either the new or old knowledge. Piaget's constructivist theory supports this view by proposing that learning occurs through two mental processes: accommodation and assimilation (Piaget, 1964). Additionally, instructors in IBL are not viewed as sources of information but rather as resources for learning (Mbata et al., 2025). Their primary role is to create a supportive environment that encourages discovery and knowledge construction. Piaget's theory asserts that the instructor is not to pump knowledge into students. Instead, the teacher is to create a conducive environment for discovery through the provision of the necessary resources

and guidance to the learners to acquire new knowledge or modify existing understanding to accommodate new information (Jonassen, 1991). The level of inquiry also tends to become less structured as students progress through higher levels of study and their cognitive development advances (Mbata et al., 2025). Lower-level students often engage in more structured inquiries, such as confirmatory and guided inquiries. In contrast, students at higher levels are believed to be capable of conducting independent inquiries, which grants them greater autonomy and responsibility. Piaget's constructivism explains this progression by outlining the stages of cognitive development, emphasizing that during adolescence, learners enter the formal operational stage, where they can formulate and test hypotheses (Piaget, 1964). This qualified Form Three students to conduct open and guided inquiry.

Although researchers like Mbata et al. (2025) used this learning theory in the recent past, they pointed out that it places a high cognitive demand on learners, especially those with limited prior knowledge; it's time-consuming; and students are at risk of misconceptions, especially when not guided properly during learning. Constructivist Learning Theory therefore, justifies the process of acquiring knowledge in IBL, where students discover knowledge by themselves under minimized teacher guidance.

2.2.2 Constructionism learning theory (Seymour Papert, 1980)

IBL is an instructional strategy that focuses on students discovering knowledge by themselves instead of passively getting it from the instructor (Mrosso et al., 2025). The emphasis is on students' activities rather than teachers' actions. In constructionist theory, Papert refers to it as "mathetics" _ a focus of instruction on how students learn rather than how they are taught (Papert, 1991). IBL proponents also emphasize hands-on experiences involving physical manipulation and practical activities, which are consistent with Seymour Papert's constructionist theory, which suggests that learners thrive when they create physical objects, arts, or models that can be shared and discussed within a community (Kafai & Harel, 1991). In both open and guided levels of inquiry, students developed project models in groups, supporting constructionist principles of hands-on activity and "bricolage." Bricolage describes the shift from individual to communal construction of knowledge, emphasizing collaboration and discourse in learning (Papert, 1991). Students in open and guided inquiries designed their inquiry processes independently, adjusting them appropriately during the

investigation, to solve the problem at hand. The constructionist theorists concur with the IBL educationists by positing that, rather than following a predetermined plan or strict logical rules, students are guided by their ongoing work (Papert, 1991). Furthermore, students learn how solutions develop without worrying about universals or broad generalizations.

The researchers who have used this teaching and learning theory in the recent past also pointed out that it requires adequate tools and technology which may not be readily available in all schools (Mrosso et al., 2025). Constructionism Learning theory hence explains the inclusion of projects in the school curriculum as a method of learning, especially in STEM disciplines like physics where students construct physical models and engage in several hands-on activities.

2.3 The conceptual framework

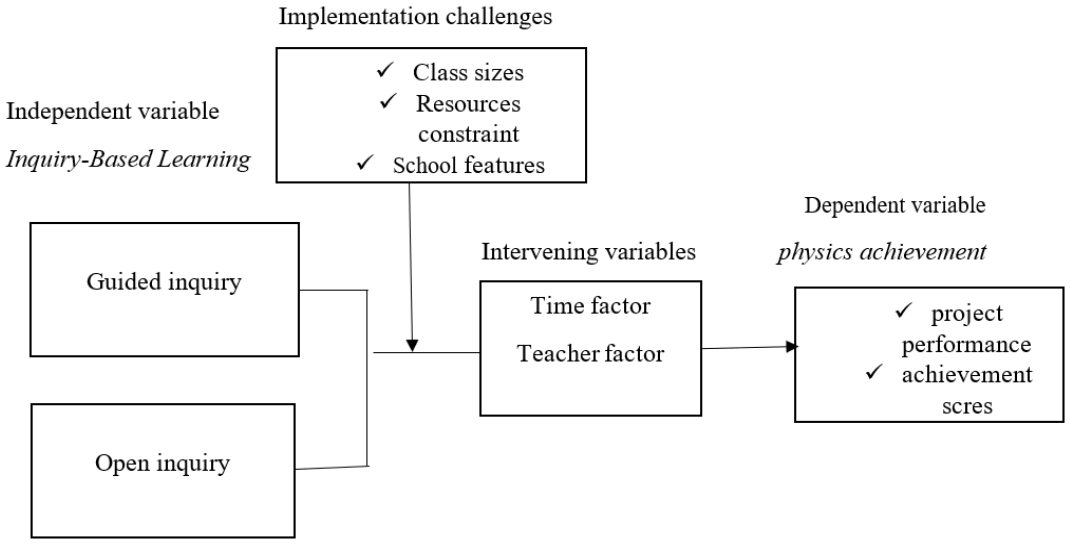


Figure 2. 1: Conceptual framework for the interaction between inquiry-based learning and physics achievements

As shown in Fig. 2.1, the researcher conceptualized that guided and open inquiry could have a statistically significant effect on students' performance in physics projects and achievement scores, under the influence of time and teacher factors. The time factor was adjusted by having one hour additional in the evening for both the control and the experimental groups for adequate inquiry exercise. The teacher factor on the other side was controlled by inducting them ahead of the exercise, on the extent to which they would go, while offering guidance in the inquiry classes.

2.4 Empirical review

This section comprises a brief concept of physics performance as adopted in this study, and the literature review based on the objectives' themes. It reviewed empirical literature on the effect of guided and open inquiry on students' performance in physics projects, their effect on students' physics achievement scores, establishing a stronger predictor of students' physics achievement scores and project performance between open and guided inquiry, challenges teachers face in their attempt to implement IBL in physics instruction, and a summary of the research gap.

2.4.1 Physics Academic Achievement

Physics academic achievement refers to learners' demonstrated mastery of physics concepts, as determined by assessments developed according to curriculum specifications (Zheng et al., 2022). Such achievements can be measured through written tests, practical exams, or project-based tasks, which evaluate the level of conceptual understanding, the ability to solve authentic problems, and the transfer of knowledge from the learning environment to real-world situations (Zheng et al., 2022). Academic achievement in physics is a clear indicator and manifestation that can be used to evaluate not only the effectiveness of an educational system but also the level of personal development of learners (Zheng & Mustappha, 2022).

Available literature offers empirical and theoretical evidence showing that physics academic achievement is multifaceted, encompassing objective and subjective dimensions (Araujo, 2017); broader and narrower aspects. This study focuses on the objective dimensions that can be measured through procedural and descriptive knowledge, as well as test scores (Araujo, 2017). These objective indicators of educational achievement are assessed using standardized tools. The two levels of achievement examined in this study are physics achievement scores, obtained through physics tests, and project performance, evaluated through hands-on activities scored by an analytical rubric. The impact of academic achievement on parents and students—including decisions about schooling, careers, and other life aspects has drawn attention from researchers both nationally and internationally (Costa, 2024). There is a need to identify factors influencing students' physics achievements and explore ways to maximize them for better outcomes. Among the various intrinsic and extrinsic factors affecting academic achievement, the instructional approach used in

the classroom is one of the most significant (Dings & Spinath, 2021). Therefore, this study embarked on investigating how instruction through IBL can be optimized by selecting the appropriate level of inquiry to be implemented in a physics class. Scores from physics achievement tests and project performances were used to analyze the effect of IBL on students' overall physics performance.

2.4.2 The effect of guided and open inquiry on students' performance in physics projects

In America, a case study was conducted with one first-generation introductory physics student at Portland State University to evaluate the effectiveness of a new 'Design-Your-Own-Experiment' (DYOE) curriculum in enhancing performance in Physics projects (DeStefano & Widenhorn, 2024). This curriculum was built on an open inquiry framework, with the focus on student conducting experiments at home during the COVID-19 pandemic using locally available materials of their choice. The phenomenon under investigation was the formation of a design that was in the shape of a ring, created by a ray of a laser being reflected in a shallow pool of water. The student had the autonomy to select equipment and tools, develop procedures, and carry out the inquiry. The study found that the student gained significant skills in general experiment design. The student was able to choose a relevant and researchable topic, identify important and negligible variables, and identify the relevant quantities to be investigated. While experimenting, the student showed skill by adapting the design when necessary. The student exhibited competence in collecting and analysing data, plotting all uncertainty bars, and presenting all estimated measurement uncertainties. However, the separation distance between the student and the learner could make the student get support from more knowledgeable others at home. This could interfere with the credibility of the student's improvement. Therefore, a study with the instructor and the respondents in the same learning environment, as the current one was done, could lead to more reliable outcomes. Additionally, for more rigorous results, a range of respondents need to participate in the study, unlike one as shown in the study of DeStefano & Widenhorn (2024). The current study had 182 respondents for more vigorous outcomes.

In Europe, a mixed study design was adopted to study how guided inquiry-based learning is conducted in Hungarian school chemistry classes (Orosz et al., 2023). To

accomplish this, 88 9th-grade students were asked to inquire about what happened to horn salt, whose scientific name is ammonium bicarbonate (NH_4HCO_3), which spontaneously disappeared from the bag in which it was placed. Their work project was evaluated by the rubric method and the students' worksheet. The study found that the students were proficient in handling experimental equipment and implementing experimental procedures. Most of the groups, despite not being given the manual detailing how the apparatus was to be assembled, could organize the components into meaningful combinations for reliable observations (Orosz et al., 2023). Additionally, Spearman's correlation coefficient revealed that the students' worksheet scores and the rubric marks were moderately positively correlated. A mixed study approach used by Orosz et al (2023) is suitable for capturing both quantitative and qualitative dimensions of a strategy, but the researchers were limited only to the operations in the laboratory and did not follow up on the postlaboratory actions, such as lab report development, that would complete the project assessment. The current study assessed students' actions in the post-laboratory activities for a complete performance in project work.

A quasi-experiment conducted with 82 participants, purposively sampled, investigated how guided-inquiry-based experiments influenced the Tanzanian ordinary level secondary school students' attainment of physics practical skills. The study revealed that such experiments led to noticeable improvements in practical skills (Mbata et al., 2025). Specifically, it enhanced students' abilities in designing experiments, executing them, analyzing data, and evaluating findings. Students who engaged in teacher-led experiments could not explicitly demonstrate all these skills. Researchers reported that these students (who engaged in teacher-led experiments) simply memorized and repeated procedures from manuals, with very limited development of practical physics skills. The study of Mbata et al (2025) involved two schools. The current one had four schools, which provided a good sample size.

In Kenya, Kunga (2021) conducted mixed research together with a quasi-experimental design, particularly Solomon's four non-equivalent control groups, to investigate the effects an inquiry-based science instruction had on learning achievements of secondary school physics students in Kitui County. The researcher purposively sampled four intact classes with 160 participants to represent the targeted population

of 1600 students enrolled in Form four in the extra county secondary schools in Kitui County. Task competence tests and student questionnaires were the major data collection tools. The students who had experienced the IBL approach outperformed their counterparts in the conventional lecture method by a very large margin upon administration of a post-test to assess the difference in task competencies. The foregoing study conducted by Kunga (2021) addressed IBL in general. The current research narrowed to only two IBL approaches, that is, open and guided inquiry.

2.4.3 The effect of guided and open inquiry on students' physics achievement scores

The effectiveness of guided inquiry over a teacher-directed approach to instruction has been validated in Saudi Arabia (Almuntasheri et al., 2016). A correlational study was adopted, and 107 6th-grade students and six teachers were randomly selected to take part in the research exercise. The students were randomly divided into either a guided-inquiry or a teacher-directed classroom. The teachers were also equally divided into either of the classes. The study compared professional development for guided-inquiry-based instructors to counterparts who practiced a traditional teacher-directed approach in helping Saudi students understand density. The results of the research study revealed that students instructed through guided inquiry had a better understanding of the topic than their peers taught by lectures. The guided-inquiry students outperformed their teacher-directed counterparts on multiple-choice questions and excelled in open-ended questions that required explanations and essays (Almuntasheri et al., 2016). However, the students in guided inquiry still did not attain the best explanation of scientific concepts. Their explanations were still more linear relationships. The students had difficulties showing interconnectedness between three or more concepts (Almuntasheri et al., 2016). This study in Saudi Arabia was done with 6th-grade students. The current was designed to be done among Form three physics students.

A quasi-experiment that administered both a pre-test and a post-test was used to investigate the effect of three approaches to inquiry on the enhancement of teacher candidates ' understanding of scientific concepts within the elementary schools (Artayasa et al., 2018). 154 students sampled from Indonesian secondary schools were divided into a teacher-led class, a guided inquiry class, a structured inquiry class, and

an open inquiry class. Based on the achievement scores of the post tests administered to each class, those who engaged in open inquiry had the best improvement in science concept understanding. Since students in open inquiry formulated the research questions and procedures on their own, they spent a substantial amount of time reviewing relevant literature. These students ended up raising several research questions beyond what the teacher gave them in other forms of inquiry. In the quest to answer the inquiry questions raised, students in open inquiry ended up discussing several science concepts, leading to a better understanding, as reflected in their test scores. The findings were that the open inquiry positively influenced students ' higher-order thinking skills, like creativity, innovativeness, critical thinking, and the ability to think logically. All these higher-order thinking skills enhanced students' conceptual understanding, which led to better scores in the post tests (Artayasa et al., 2018). This finding of Artayasa et al. (2018) could explain the results of Almuntasheri et al. (2016) who provided that students in guided inquiry could only expain linear relationship between concepts and could't show interconnectedness between more concepts. Artayasa et al. (2018) provides that students master interconnectedness between concepts when they raise their own inquiry questions and conduct numerous inquiries with the quest of answering them. While the respondents in Artayasa's study were university students, the current study employed secondary school students to examine whether the approach could yield improvements even among juniors.

Researchers in Nigeria aimed to examine how Vee-Diagram and guided-inquiry strategies impacted physics achievements among secondary school students. The researchers used a multistage sampling technique to select 413 students taking physics in senior secondary two (SS2) to represent the target population of students from 707 public secondary schools in the state. A quasi-experimental design involving pre-test and post-test assessments was employed. Physics achievement tests (PATs) served as the primary tools for collecting data on students' performance in both the experimental group (handled with Vee diagram and guided inquiry) and the control group (taught using traditional lecture methods). The mean, standard deviation, and ANOVA results from the pre-test indicated no statistically significant difference in achievement scores among students across the three instructional methods: Vee diagram, guided inquiry, and conventional lecture. The pre-test mean scores were 15.2, 15.8, and 16.0, respectively, while the post-test scores increased to 25.6, 27.0, and 20.5. The results

clearly show that although all three interventions led to statistically significant improvements, the mean score was highest for guided inquiry, indicating that students benefited most from it. The researchers attributed this notable improvement to the high level of student involvement and engagement in the inquiry process (Abdulmalik Olayinka Anwo et al., 2025). The described research in Nigeria evaluated the significance of the Vee diagram and guided inquiry compared to traditional lecture methods. The current one aimed to assess the effectiveness of guided and open inquiry, based on scores from the PAT and performance in physics projects.

To investigate the effectiveness of guided inquiry in enhancing students' ability to comprehend physical and chemical changes in chemistry among seventh-grade students in the Amhara regional state of Ethiopia, a researcher purposively sampled one elementary school with the highest population in terms of students in the state (Berhanu and Sheferaw, 2022). From the school, the researcher randomly sampled two intact classes with a total of 55 students who were the respondents of the study, and randomly assigned them to either an experimental or a control group. The study applied a quasi-experimental design that allowed the researchers to administer pretests and posttests to nonequivalent control and experimental groups. The independent t-test conducted before the intervention showed a negligible difference between the two groups taught with guided inquiry and the one trained with teacher-centered lecture methods. After the intervention, both independent and paired t-test analyses revealed that students who engaged in guided inquiry achieved significantly higher scores in concepts related to physical and chemical changes than those taught with traditional lectures. The researchers concluded that guided inquiry is a more effective classroom instruction strategy than the conventional lecture method (Berhanu and Sheferaw, 2022). While the study of Abdulmalik Olayinka Anwo et al. (2025) took caution to reduce the threats to internal validity like maturation and social interaction, by using different schools and intact classes, Berhanu and Sheferw (2022) used one school from which two intact classes were sampled. This could allow social interaction between the two groups in which different strategies were used, thereby causing possibility of contamination and spillover effects. The current study was done in four different schools to prevent the spillover effects and contamination. In addition, Berhanu and Sheferaw (2022) conducted their study in Chemistry. The current study was done in

Physics to determine how the teaching approach influenced students' achievement in other science subjects.

In Kenya, Wabuke (2016) aimed to examine the effectiveness of IBL in enhancing students' general scientific skills and specifically Biology achievement among the students in secondary schools in Wareng sub-county. The quasi-experiment used Solomon's four non-equivalent design. The sampling techniques used to select 220 Form Three students from a total population of 2594 students were stratified and simple random. The students in two distinct non-equivalent groups took the Biology Science Process Skills Achievement Test (BSPSAT) before and after the intervention. Additionally, learners responded to questionnaires to share their views on IBL. While comparing the achievement of the two groups, the researcher employed an independent t-test and ANOVA. Results revealed that the experimental group students demonstrated greater gains in science-specific skills and higher test scores than their counterparts taught by traditional lecture methods. This study generalized the application of IBL. The current study focused on guided and open inquiry.

Literature search showed that though there were different conditions under which the effectiveness of IBL strategies was examined across different science subjects, most of them used a quasi-experimental research design. This justified its selection even in the current study.

2.4.4 Comparing the relative predictive strengths of guided and open inquiry in enhancing students' physics achievement scores and project performance

A study to compare the short-term and long-term gain in students' scores, together with a change in attitude toward Physics, between students under guided and open levels of inquiry in America employed a quasi-experiment that involved a post-test among non-equivalent groups (Guisti, 2008). The study was done among the sophomores, juniors, and seniors of Lone Peak High School. The researcher divided four sections of introductory physics into two sections and randomly assigned each to either guided or open inquiry. The Force Concept Inventory (FCI) and the Utah State Criterion-Referenced Physics Test (CRT) were the instruments for determining the level of concept grasping. The Colorado Learning Attitudes about Science Survey (CLASS) determined the shift in students' attitudes towards learning physics. The number of students who responded to FCI and CRT till the end of the interventions

was 44 and 42 for open and guided, respectively, while for CLASS, they were 41 and 40 for guided and open, respectively. CRT revealed two different results. For the first post-test administered after the two interventions, the normalized mean gain for an open inquiry was .40, which was slightly above that of guided inquiry of .38. When the post-test was administered again after 11 weeks, both the treatments continued to increase their scores, with the open inquiry class increasing more than the guided inquiry with a statistically significant margin. The results from CLASS revealed that both treatments had an unfavorable influence on students' attitudes towards physics, with open inquiry influencing the attitudes students had towards physics much severely (Guisti, 2008). The study by Guisti (2008) was done for a year long, with very large time lapse between pretest and posttest (11 weeks). The current study went for one month with a shorter time elapse between pre-test and post-test.

Results of Cai et al (2021), also from America, concurred with those of Guisti (2008). Cai et al (2021) qualitatively analyzed transcribed audio for a physics laboratory session to identify recurring themes. The laboratory sessions were done by second-year undergraduate physics students. 8 pairs of students conducted open inquiry, while 5 pairs conducted guided inquiry. Their study revealed that students in the guided group mainly concentrated on adhering to the procedures given for the completion of the work, while those in the open inquiry explored a range of alternatives, which enhanced their creativity and critical thinking. Additionally, whenever the investigation did not come out as prescribed for the students under guided inquiry, it was observed that they became confused and frustrated. On the contrary, students under open inquiry embraced the challenges encountered and used them as opportunities to configure and troubleshoot their tools and procedures (Cai et al., 2021). However, the foregoing study analyzed only qualitative data in the form of a transcribed audio. Supplementing qualitative data with quantitative aspects always boosts the validity of the findings, as done in the current research through implementation of validated data collection tools such as laboratory rubrics and physics achievement tests to collect data.

Researchers designed a quasi-experimental design to compare which one among structured, guided, and open inquiry is best for classroom implementation in Indonesia. The study targeted students who were being trained at the University of

Mataram as elementary school teachers (Artayasa et al., 2018). The researchers used a cluster random sampling technique to sample 154 students for the study. The Science Concept Test was the major instrument for data collection. The study findings revealed that students who conducted open inquiries had the highest improvement in understanding science concepts (Artayasa et al., 2018). The researchers attributed this higher improvement to students' effort in preparation, literature searching, comprehending the procedures, and variable manipulation. In addition, the responsibility given to the learners to take full lead over their work made them think widely, logically, and more scientifically. Guided and structured inquiries were reported to be solving only questions generated and presented by the lecturer to the students, unlike in open inquiry, where the rigorous development of research questions and search for solutions make learners more competent in the field of inquiry (Artayasa et al., 2018). This study in Indonesia was conducted at a tertiary level of learning. The current was done in a secondary school setup.

A longitudinal study was conducted with 50 high school biology students observed over their two-year inquiry learning process during 11th and 12th grades (Sadeh & Zion, 2009). The observations took place as students prepared for their matriculation exam in Israeli public secondary schools, aiming to compare guided and open inquiry to determine which approach better enhanced the acquisition of inquiry performance skills. Data were collected through interviews, students' inquiry papers, logbooks, and reflections. Thematic analysis was used to analyze the qualitative responses, alongside a MANOVA test to compare the two groups. The study found that the open inquiry students demonstrated higher mastery of these skills than their guided inquiry counterparts. The researchers recommended future studies with larger sample sizes for better representation of the population (Sadeh & Zion, 2009). Unlike the reviewed study, which involved only 50 students, the current research includds 176 students, providing a more representative sample of the population in Suba South Sub-County. Additionally, the researcher here used tools such as logbooks, interviews, and students' inquiry papers which only presented qualitative data. The researcher in the current study used tools such as laboratory rubrics and physics achievement tests which gave quantitative aspects.

A quasi-experiment involving assessments before and after the intervention was used to evaluate the suitability of guided and open inquiry in enhancing the achievement of Biology students among senior secondary one (SS1) students in Osun State, Nigeria (Owolade et al., 2022). Multistage and purposive sampling techniques were used to sample three intact science classes, since only science classes took Biology. A total of 118 students were sampled to take part in the study. The tools for data collection were the Biology Process Skills Observation Checklist and Biology Self-efficacy Rating Scale. The hypothesis testing by ANCOVA showed that although students in both groups showed a significant improvement, the gains among those under open inquiry were notably greater than those in the guided inquiry group. Some explanation for the significant improvement among open inquiry students is that this strategy fosters better teacher-student relationships, enhances students' well-being at school, and fosters a sense of belonging and responsibility over their work. Guided inquiry also demonstrated statistically significant improvements in Biology students' performance compared to those taught with conventional lecture methods (Owolade et al., 2022). However, the foregoing study was conducted in Biology. The current was done in Physics, with form three students as the respondents.

Mbata et al (2025) compared the four levels of inquiry to determine which one was the best in physics instruction to enhance the mastery of practical skills. The researchers selected 82 students who were in their ordinary level in Tanzanian secondary schools. The researchers purposively sampled two schools that had similar characteristics. Data collection instruments were physics practical, practical skills observation rubric, and laboratory worksheets. Constructivist learning theory was the theoretical framework that guided the study of Mbata et al (2025). The results of their quasi-experimental design revealed that the two most structured levels at the lowest levels of inquiry, that is, confirmatory and structured, where students are given both the research question and procedures, do not form part of inquiry, but rather traditional-based experiment (TBE). They argued that the next two levels, which are guided and open inquiries, are the major types of inquiry learning in the sciences. Open inquiry was criticized for being too difficult to translate into real classrooms and being too abstract for students, especially the novice, to formulate sensible research problems. Mbata et al (2025) concluded by emphasizing guided inquiry for its ability to develop practical skills among learners. Their criticism of confirmation and

structured levels was that they lead to rote memorization and replication of procedures, without developing rigorous practical skills in Physics. The study by Mbata et al (2025) was guided by constructivist theory alone. The current one employed constructionist learning theory, in addition to the constructivist learning theory.

It was evident from the studies of the early researchers that most of them used tools that only collected qualitative data (Owolade et al., 2022; Sadeh & Zion, 2009; Cai et al., 2021). A study that used quantitative data collection instruments was necessary to supplement the findings from the quanlitative data collection tools. The surrent study incorporated the two approaches of data collection for more valid results.

2.4.5 Challenges of using IBL for physics instruction.

Mixed-method research was designed to study the challenges and opportunities of IBL in teacher training (Torres et al., 2022). 60 physics students were sampled from the School of Education, University of Antioquia, South America. A Likert-type questionnaire was the primary data collection tool. Four exploratory interviews followed this to gain a broader understanding of students' views on inquiry-based science learning. Researchers used software that could analyze qualitative data and Microsoft Word to analyze the responses from the interviews. The study revealed that despite the long duration of the push for better science education through IBL, educators have been hesitant to adopt it due to challenges such as frustration over limited time, resource constraints, the complexity in managing IBL classrooms, the demands of curriculum delivery, and the difficulties in assessing learning in IBL (Torres et al., 2022). The respondents in the research of Torres et al. (2022) were student teachers who were still undergoing training. Using already in-service teachers would have been much more appropriate. Teachers who had experienced the IBL strategy in action would have given even more reliable results. The current study used in service teachers who used the IBL approaches for classroom instruction.

A survey study conducted in Croatia, Europe, to explore the opinion of teachers concerning the drawbacks hindering the implementation of inquiry-based learning in primary science classes (Letina, 2021) sampled 365 teachers as the respondents to a specially designed questionnaire that was adapted from Ibrahim's instrument to measure teachers' beliefs and experiences on inquiry-based learning (Ibrahim, 2003).

The data collected was analyzed using the Statistical Package for Social Sciences (SPSS). The findings presented different categories of the challenges as follows: time challenges, organizational barriers, student characteristics and competencies, teacher competencies, and a lack of support for the implementation of IBL. The teachers complained about insufficient time for adequate preparation and covering the extensive curriculum. The components of organizational barriers were the complexity of the inquiry-based teaching organizational, class-subject system that dominated the schools, inadequate textbooks, the high costs of equipment for experimentation, and the unavailability of the appropriate materials for inquiry. Student characteristics that hindered IBL implementation were poor students' working attitude towards conducting inquiry, difficulties in motivating students to conduct research, difficulties in managing inquiry classes, and maintaining students in the inquiry process. It was also identified as challenging to teach students with learning difficulties through IBL. IBL could also not accommodate all learners, all age brackets, and all educational levels. Finally, assessing students' achievements under IBL instruction was a major challenge. It is plain that the already in-service teachers used in Croatia by Letina (2021) were much informed on the challenges compared to the student teachers used in America by Torres et al (2022).

In the United Kingdom, Moseley & Connolly (2021) designed Case studies that used observations and surveys to collect qualitative information on the benefits and challenges of implementing IBL in learning public administration. The views of the postgraduate students and educators were collected and analyzed. The study revealed that IBL was so demanding for students who were used to structured teacher-based instructions. IBL required more independent learning, which scared most students. The modes, including group work, in which IBL was delivered, seemed to be too demanding to several learners (Moseley & Connolly, 2021). The high time and resource demands of IBL posed a major drawback. Additionally, educators had a limited understanding of how IBL should be best implemented and facilitated. Finally, students' satisfaction was relatively diminished under IBL approaches due to the unfamiliar nature of the tasks they were required to engage in (Moseley & Connolly, 2021). Moseley & Connolly (2021) provided that if student teachers must also give their responses, then they should respond alongside experienced teachers, and not independently as Torres et al did.

Other researchers conducted a qualitative study in the Philippines among STEM students in the 12th grade who learned physics by IBL instruction (Bogador et al., 2024). The major aim of the study was to understand the drawbacks and the benefits of adopting this kind of physics instruction. The researchers purposively sampled ten students. One-on-one interviews were the major data collection instrument. The study revealed three challenges of the approach: challenges of solving abstract problems, incompetence in handling laboratory activities, and comprehending theoretical concepts. Physics, being an elemental science, has a theoretical framework, mathematical configurations, and physical quantities that can be measured. This combination of theoretical concepts and rigorous mathematical elements made physics learning so abstract and challenging for students, especially when left to discover on their own under IBL approach. Designing experiments that were both sensible and safe was also a major challenge acknowledged by the students. In understanding the concepts of physics, students pointed out that they needed a blended knowledge of the theoretical basics, performing calculations that involved mathematical expressions, and carrying out hands-on laboratory operations. Understanding all these concepts holistically was found to be challenging for the students. The findings of the researchers in the Philippines deviated from those of other researchers. None of the researchers had presented the challenge of IBL in enhancing concept grasping. Bogador et al. (2024) present the challenges of IBL that hinder abstract physics concepts, giving new insights that challenges toward IBL implementation must not revolve around limited time, resources, and limited knowledge on its implementation, but can also relate to content mastery.

In Pakistan, a quantitative research survey design that employed a multistage sampling technique was used to investigate the benefits and challenges of adopting IBL in instructing pupils in elementary education (Kausar et al., 2024). Three hundred teachers were sampled from both private and public schools in that region. Open-ended questionnaires were the data collection instruments. The study revealed four challenges that mostly affect the proper implementation of IBL: time constraint, need for teacher training and support, resource limitation, and balancing IBL with structured curriculum requirements. The teachers identified that, given their packed curriculum, they could not allocate adequate time for students to explore, ask questions, and experiment. Teachers also identified that proper implementation of IBL

needed a specialized kind of professional training on organization and putting into practice the approach in such a way to encourage constructive exploration. The teachers identified that they lacked the necessary training, and suggested the relevant in-service training for them, if they had to adopt the new approach. IBL was also identified as needing several resources and specific tools and equipment for exploration and experimentation, which the schools sometimes could not purchase. Striking a balance between the demands of the curriculum and the needs of IBL was a major challenge. Teachers claimed that the curriculum had very strict benchmarks they had to meet, which sometimes contradicted the explorative nature of IBL (Kausar et al., 2024).

Roslan et al. (2023) conducted qualitative research that examined the challenges that teachers of physics in Malaysia faced in their attempts to implement IBL instruction. The researchers used interviews to collect qualitative data from three physics teachers who were purposively sampled from various learning institutions. The research found that teachers faced both challenges that stemmed from individual teacher incompetence and those from the school context. Intrinsic was a term used to refer to challenges that stemmed from an individual teacher, while extrinsic was used to refer to those from the school context. The extrinsic challenges were a lack of confidence among the students in learning physics using IBL approaches, limited time, and resources to teach physics using IBL. Low level of students' efficacy and confidence when learning physics by IBL hindered their full participation and engagement. It was also identified that the students preferred the traditional teaching approaches, hence tended to reject the new, unfamiliar IBL approach. Some of the intrinsic challenges, on the other hand, were limited experience in conducting constructive inquiry-based learning in physics classes and inadequate competence in the mastery of physics content. There was a disparity between how teachers were trained in training institutions and the requirements of IBL. This made the teachers have a feeling of low self-efficacy and diminished confidence to implementing such an approach.

2.5 Chapter Summary

Most of the literature reviewed indicated that guided and open inquiry have positive impacts on improving students' practical performance in physics and their physics achievement scores (DeStefano & Widenhorn, 2024; Orosz et al., 2023; Mbata et al.,

2025). When comparing which method was a stronger predictor of students' project performance and physics scores, different studies offered varying findings. Some favored guided inquiry for its ability to provide scaffolding while giving students enough autonomy, and they claimed open inquiry is too challenging to implement in classrooms (Mbata et al., 2025). Conversely, most studies supported open inquiry, arguing that the autonomy it provides encourages students to think like scientists and become problem solvers rather than just follow step-by-step procedures (Owolade et al., 2022; Artayasa et al., 2018; Cai et al., 2021; Guisti, 2008).

Literature reviewed included studies conducted at tertiary levels (Artayasa et al., 2018; Cai et al., 2021), while others focused on elementary levels (Almuntasheri et al., 2016; Berhanu and Sheferaw, 2022). Some studies involved Form One students as participants (Owolade et al., 202), whereas others involved Form Two students (Abdulmalik Olayinka Anwo et al., 2025). The current study was conducted in secondary schools with Form Three students as respondents. Some studies employed correlational methods (Almuntasheri et al., 2016), others used mixed-methods approaches (Orosz et al., 2023; Kunga, 2021), and some adopted longitudinal designs (Sadeh & Zion, 2009). The current study used a quasi-experimental design with pre- and post-tests. It was also identified that most of the studies employed qualitative data collection instruments and did not focus mch on the quantitative dimensions (Owolade et al., 2022; Cai et al., 2021). The current study employed both quanlitative and quantitative data collection tools for reinforcement of one another. Additionally, some of the reviewed studies focused on achievement in Chemistry (Orosz et al., 2023; Berhanu and Sheferaw, 2022), Biology (Wabuke, 2016; Owolade et al., 2022), or science in general (Artayasa et al., 2018). The current researcher conducted the study in physics.

Most studies took place beyond the borders of Kenya, with very few within the country. Conducting the current one in Kenya may provide empirical evidence to local curriculum developers and diversify the context of the available body of literature. Additionally, some studies were done in only one school (Guisti, 2008), others in two schools (Mbata et al., 2025). The current one was done in four schools.

While reviewing on the challenges hindering the implementation of IBL strategies, most studies presented the challenges of time constraints, limited resources, the

structure of the secondary curriculum that does not allow room for inquiry based learning, and limited knowledge on designing and implementing IBL strategies (Torres et al., 2022; Letina, 2021). But Bogador et al. (2024) gave a rarely mentioned but acute challenge of IBL. They mentioned that some teachers are reluctant to implement IBL in physics classes because the abstract physics concepts reinforced with mathematical concepts which students cannot readily grasp on their own under inquiry strategies unless they are exposed to them step by stem in conventional teacher lecture methods. But all these challenges were reported by researchers who conducted their studies beyond the boarders of Kenya. Adapting a similar research within Kenya was so necessary to determine whether these challenges are also experienced in Kenya, or whether the condition in Kenya is unique and doesn't suffer these challenges.

There have been inconsistent findings on how IBL enhances comprehension of STEM concepts. The findings variation on how IBL instruction relates to learning outcomes, especially in science-related disciplines, presented the need for future researchers to make a close examination of the level of inquiry results to the most negative or positive impacts on students' learning outcomes in the disciplines (Wang et al., 2022). They added that to date, there is still a debate on which level of inquiry maximizes students' academic achievements.

Finally, in Kenya, as far as the literature search for this study was concerned, no study had concentrated on open and guided levels of inquiry in enhancing students' achievement in physics laboratories and classes. Researchers have been called to design studies that can investigate how different levels of inquiry learning correlate with learners' academic achievement (Nzomo et al., 2023). This study aimed to address the discrepancies in these previous studies by giving a precise look into open and guided inquiry in physics laboratories.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter delineates the research methods that was employed in this study, encompassing the research design, study locale, target population, sampling methodologies, sample size, data collection instruments, validity and reliability, piloting, data collection processes, data analysis, and ethical issues.

3.2 Research philosophy

The study is anchored in the pragmatism research philosophy, which prioritizes approaches that best address the research problem over adherence to a single methodological tradition. Pragmatism holds that knowledge is constructed through practical consequences and real-world applications, making it well suited to studies seeking both explanation and understanding. In this research, which examines the effects of guided and open inquiry-based learning (IBL) on students' academic achievement in physics, pragmatism enables the integration of quantitative measures (such as achievement scores and project performance) with qualitative insights (such as teachers' experiences and challenges). This philosophical stance supports a mixed-methods approach, allowing the researcher to draw on the strengths of both paradigms to generate comprehensive, contextually relevant findings (Creswell & Creswell, 2022). Furthermore, pragmatism aligns with the quasi-experimental Solomon's Four-Group Non-Equivalent Control Design adopted in this study, as it prioritizes the practical evaluation of interventions in real educational settings. By focusing on "what works" to improve physics achievement, the philosophy permits flexibility in data collection and analysis, allowing the researcher to examine causal relationships while also capturing participants' perspectives. This was particularly important in the context of secondary schools in Suba South Sub-County, where educational practices are influenced by contextual factors that require both numerical evidence and descriptive explanations. Thus, pragmatism provided a robust philosophical foundation for integrating diverse forms of data, enhancing the validity, applicability, and overall depth of the study's findings (Saunders et al., 2023).

3.3 Methodology

This study adopted convergent parallel mixed methods research in which qualitative and quantitative data were collected within the same phase of the study and analyzed separately. The quantitative data were collected under Solomon's four-group design using achievement tests and project tests, while the qualitative data were collected by the use of interviews and questionnaires. The analysis of the qualitative data helped explain why teachers were reluctant to adopt IBL in classroom instruction, despite its potential to enhance students' physics achievement.

3.4 Research design

According to Creswell & Creswell (2022) and Saunders et al. (2023), a research design is a proposed plan of how research will be conducted, showing how philosophy will interact with inquiry strategies and specific methods. Furthermore, this study adopted a Quasi-experimental Solomon's Four-Group Non-Equivalent Control Design for the quantitative data. This design enabled the determination of causal relationships between IBL and students' physics achievement, including assessing whether the effects on the physics achievement result from the interaction between pre-test and treatment (Kunga, 2021). Furthermore, this design enabled the identification of two comparable groups with similar characteristics. Since school authorities often do not permit reconstituting intact classes for research, two of the sampled schools' physics classes were randomly assigned as experimental groups, while the remaining two served as control groups.

Table 3. 1: Solomon's Four Non-equivalent Control Group Design (as Adapted from Kunga, 2021)

Group	Design Group	Pre-test	Treatment	Post-test
1.	Experimental, E1	O1	X_1	O2
2.	Control, C1	O3	X_2	O4
3.	Experimental, E2	-	X_1	O5
4.	Control, C2	-	X_2	O6

Key: E1 and E2 Experimental groups 1 & 2

C1 and C2 Control groups 1 & 2

O1 and O3 Observation at the pre-test phase

O2, O4, O5, O6 Observation at post-test phase

X Shows the intervention

---- Shows the groups are non-equivalent

Table 3.1 shows Solomon's Four Non-Equivalent Control Group Design adopted for this research. Two mixed schools, one boys' school and one girls' school, were purposively sampled. One of the mixed schools and a boys' school were randomly categorized as control groups, while the other mixed school and the girls' school were categorized as experimental groups. The two control groups were instructed by guided inquiry, while the other two experimental groups were instructed by open inquiry. According to Lavrakas (2008), control groups can also be given a different intervention from that of the experimental group. Additionally, Mai et al. (2020) compared the effectiveness of two transfer interventions using Solomon's four control group designs. E1 and C1 were administered a pre-test before the treatment. The observations of the pre-test were registered as O1 and O3, respectively. After experiencing the interventions for a whole topic of refraction of light, all four groups were given a post-test, and observations were registered as O2, O4, O5, and O6, respectively. The omission of pre-testing among the experimental group two and the

control group two was necessary to reveal any relationship between the intervention and the pre-test.

3.5 Locale of the study

The location of the study was Suba-South Sub-County, which is an electoral constituency under the Independent Electoral and Boundaries Commission (IEBC) with code number 252 (NGCDF Suba South Constituency, 2025). It is among the eight sub-counties in Homa Bay County (code 043), in the Nyanza region of Kenya (NGCDF Suba South Constituency, 2025). There are 39 public secondary schools in the sub-county, with 33 being mixed schools, 2 boys' schools, and 4 girls' schools (MoE Kenya, 2025). The major economic activity in the Sub-County is farming. Most of the residents in Suba South Sub-County live below the poverty line at 48.4%. This high poverty rate in the region is attributed to the harsh climatic conditions and the use of outdated farming methods, which do not yield quality produce. In addition to the rampant subsistence farming in the region, fishing is also practiced in Lake Victoria, which covers some parts of the sub-county (PesaYetu, 2023)

Just like in all other parts of the country, physics enrollment and performance in Suba South have been relatively low compared to other subjects (KNEC Report, 2017-2022). The reports showed that most students did poorly in the practical sessions. Interventions such as instructional strategies that pay more attention to practical and project work were adopted. One of such instructional strategies is IBL. Although the effectiveness of IBL students' achievement enhancement has been documented in some areas of Kenya, these studies tend to focus on regions with ample resources and infrastructure, mostly in urban settings, neglecting the contextual challenges of interior areas like Suba South. Such partial studies may fail to fully depict the varied benefits and challenges across the country (Omariba, 2023). Additionally, no research has examined how guided and open levels of inquiry impact students' Physics achievement, specifically in Suba-South Sub-County. Creswell & Creswell (2017) posit that a study research can be done anywhere and results replicated to other regions. This justified the selection of Suba South Sub-County as the study locale. The duo added that replicating the findings of a study done in a particular context to different locales helps to prove that the findings are applicable and valid, not only to a particular context but across several regions. Therefore, though this study focused

on Suba South Sub-County, the results can be replicated to inform physics instruction both in Kenya and other parts globally.

3.6 Target population

Asiamah et al. (2017) define a target population as a group of subjects who share specific attributes of interest. This study focused on Form Three students in public secondary schools in the Sub-County, along with the teachers in these schools. According to the Sub-County Director of Education's office, there were 3,312 Form Three students in these schools, with a total of 637 teachers. The cognitive level of Form Three students made them the most suitable candidates for conducting inquiry-based learning at various levels, after Form Four students, who wer excluded from the research, to allow ample time for national exam preparations.

Table 3. 2: Distribution of the target population

S/N	Name of school	category	2025 student enrollment			Teachers
			Boys	Girls	Total	
1	PSS1	MSS	45	25	70	9
2	PSS2	MSS	38	30	68	10
3	PSS3	MSS	26	22	48	13
4	PSS4	MSS	18	24	42	15
5	PSS5	MSS	33	24	57	15
6	PSS6	MSS	22	27	49	18
7	PSS7	MSS	15	26	41	11
8	PSS8	MSS	40	37	77	14
9	PSS9	MSS	54	20	74	20
10	PSS10	MSS	35	21	56	10
11	PSS11	MSS	51	33	84	12
12	PSS12	MSS	66	41	107	8
13	PSS13	MSS	34	53	87	13
14	PSS14	MSS	47	20	67	18
15	PSS15	MSS	51	34	85	12
16	PSS16	MSS	46	50	96	11
17	PSS17	MSS	62	44	106	14
18	PSS18	MSS	36	52	88	14
19	PSS19	MSS	59	58	117	17
20	PSS20	MSS	40	46	86	8
21	PSS21	MSS	39	43	82	15
22	PSS22	MSS	55	36	91	12
23	PSS23	MSS	28	44	72	12
24	PSS24	MSS	37	50	87	9
25	PSS25	MSS	61	25	86	15
26	PSS26	MSS	55	36	91	11
27	PSS27	MSS	75	53	128	19
28	PSS28	MSS	57	40	97	10
29	PSS29	MSS	23	31	54	24
30	PSS30	MSS	49	38	87	17
31	PSS31	MSS	43	27	70	10
32	PSS32	MSS	39	50	89	13
33	PSS33	MSS	46	36	82	8
34	PSS34	BSS	153	0	153	46
35	PSS35	BSS	108	0	108	33
36	PSS36	GSS	0	139	139	39
37	PSS37	GSS	0	126	126	30
38	PSS38	GSS	0	53	53	41
39	PSS39	GSS	0	112	112	11
Total			**1686**	**1626**	**3312**	**637**

Source: Suba South Sub-County Education Office (2025)

3.7 Sampling

Sampling defines the act of picking a part of the target population to represent it in a data collection activity (Amhed, 2024).

3.7.1 Sampling techniques

Sampling techniques are strategies adopted in research for selecting participants (Amhed, 2024). The three major sampling techniques that were adopted in the study were purposive, stratified, and simple random sampling.

3.7.1.1 Purposive sampling

This is one of the non-probability sampling techniques where the respondents or study sites are picked according to the preferences of the researcher on how best the sample fits the realization of the objectives and who will be most useful for the data needed (Amhed, 2024; Etikan et al., 2016). Form three class was chosen purposively due to their ability to conduct inquiry under varying extents of teacher guidance. In addition, Form Three was the most appropriate class since students here had already selected subjects to align with, making physics instruction stable and consistent compared to earlier Forms. From the teachers population in the sub-county, physics teachers will also be chosen purposively to respond to the questionnaire.

Four out of the 39 schools in Suba South Sub-County were purposively selected: Two MSS, one BSS, and one GSS. The two MSS were selected based on their similarity in the historical performance records in the previous KCSE physics exams, school culture, and the approximate number of students. Similarly, the GSS and the BSS were also picked purposively to ensure they are also identical in the above dimensions.

3.7.1.2 Stratified sampling

This technique first divides the target population into distinct, homogenous subgroups referred to as strata, based on some predefined categories, such as school categories, after which sampling is done from each stratum to ensure representativeness of the target population (Amhed, 2024; bako & Creswell, 2021). Stratification in this study was done based on the school category, namely MSS, BSS, and GSS. The rationale for employing stratification was to ensure at least one school was picked from each of the three categories to limit biased sampling and to improve the generalizability of the study findings. From the three strata, two MSS, one BSS, and one GSS were selected for participation. Form Three students in these schools were deliberately chosen since their cognitive maturity allows them to engage with IBL at both open and guided

levels. The strategy ensured that the diversity of the school environments in the sub-county was considered while comparing the physics achievements in different schools.

3.7.1.3 Simple random sampling

This is a sampling technique that gives each subject of a population an equal probability of participating in the exercise as a respondent (Omariba, 2023). Simple random sampling was used within the selected schools to pick an intact form three physics class. For the schools that had more than one stream, all the streams were given equal treatment to avoid unusual behavior among the selected streams (Clark et al., 2021).

3.7.2 Sample size

This refers to the actual number of study participants representing the targeted population for a study (Omariba, 2023). The two primary formulas used in this study were Cochran's sample size formula and the formula for stratified sampling. Cochran's (1977) formula is given by:

$$n_o = \frac{Z^2.p.(1\text{-}p)}{E^2}$$

Where Z is the z-value, e.g., 1.96 for a 95% confidence level, P is the estimated population proportion, usually 0.5 if unknown, and E is the margin of error, which will be 5% for this study

Therefore, the sample size was found by substituting values in the above formula, that is,

$$n_o = \frac{1.96^2.0.5.(1\text{-}0.5)}{0.05^2} \approx 385$$

Upon adjusting the sample size using the formula for correction provided by Israel (1992), that is, $n_o = \frac{n}{1+\frac{n-1}{N}}$ where n_o is the adjusted sample, n is the originally calculated sample size from Cochran's formula, and N is the population for the study, the sample size became $n_o = \frac{385}{1+\frac{385-1}{3312}} \approx 345$ students and $n_o = \frac{385}{1+\frac{385-1}{637}} = 240\ teachers$

The formula for stratified sampling is given by:

$$n_h = \frac{N_h}{N} \times n$$

Where n_h is the sample size for stratum h, N_h is the population size for stratum h, N is the total population size, and n is the overall sample size

From the statistics found from the Sub-County's Director of Education, the number of students and teachers respectively from the three categories was as follows: 261 and 79 from the boys' schools, 430 and 121 from girls' schools, and 2621 and 437 from mixed schools. Therefore, the stratified formula will be applied as follows:

Students sampled from boys' schools $n_h = \frac{N_h}{N} \times n = \frac{261}{3312} \times 345 \approx 28$

From girls' schools $n_h = \frac{N_h}{N} \times n = \frac{430}{3312} \times 345 \approx 45$

from mixed schools $n_h = \frac{N_h}{N} \times n = \frac{2621}{3312} \times 345 \approx 273$

for the teachers from;

boys' schools $n_h = \frac{N_h}{N} \times n = \frac{79}{637} \times 240 \approx 30$

girls' schools $n_h = \frac{N_h}{N} \times n = \frac{121}{637} \times 240 \approx 46$

mixed schools $n_h = \frac{N_h}{N} \times n = \frac{437}{637} \times 240 \approx 165$

Table 3. 3: Sample frame

Target population				
School type	**School**	**Students**	**Teachers**	**Total**
BSS	2	261	79	340
GSS	4	430	121	551
MSS	33	2621	437	3058
Total	39	3312	637	3949

Source: researcher, 2025

Table 3.3 shows the sample frame from which the sample size was drawn

Table 3. 4: Sample Size

	Sample size population	
School type	**school**	**Students**	**Teachers**
BSS	1	28	30
GSS	1	45	46
MSS	2	273	165
Total	4	346	241

Source: researcher, 2025

Table 3.4 shows the sample size that was calculated to represent the target population

3.7.3 Sampling procedure

The researcher compared the previous performance of different schools and settled on one boys' and one girls' school, which had consistently portrayed similar mean scores in physics in the previous years. This ensured comparability of the two schools and helped minimize bias in the achievement outcomes across categories. Similarly, to select two mixed secondary schools, the researcher relied on the records of previous KCSE physics results to ensure the two selected schools had also consistently recorded similar mean scores in the previous KCSE physics exams.

Consideration of multiple criteria in the selection process ensured that any variation in physics achievement was primarily due to the intervention and not external factors like the schools' historical achievement records or their size. Within the sampled schools, all teachers of physics were chosen purposively to fill in the questionnaires that inquired about the challenges faced by teachers in the IBL implementation for physics instruction. According to Omariba (2023), ensuring that schools are selected properly in line with the study objectives helps produce valid results that are comparable across different strata in educational research.

3.8 Data collection instruments

Three instruments for data collection were employed: the analytic rubric, physics achievement tests and the teachers' questionnaire.

3.8.1 Analytical Rubric

The tool of assessment mostly preferred for assessing learners' performance in practical and project activities is the analytic rubric (Kola, 2022). It is capable of assessing learners' design capability, describing the quality of performance and products to different degrees, and developing critical thinking skills among learners (Giacumo and Savenye, 2020). The analytical rubric developed for the current study entailed four phases, with different criteria in each phase. Each criterion was weighed on a scale of five, ranging from least merit to excellent.

The first phase was the planning stage, which comprised of 20% of the score. In the planning phase, the rubric examined four criteria: fundamental knowledge of the topic, ability of the student to propose a plan for the project, ability to generate and answer questions from others, and the ability for original thought. The second phase was the experimental stage. The criteria here were the ability to manipulate and properly handle apparatus, co-operation with other group members, ability of students to seek assistance from the teacher and colleagues, attitude towards practical work and the economical use of materials, and the observation and data recording skills. The criteria under post laboratory stage, which was phase three, comprised the ability to present experimental results clearly, capacity for logical analysis of results, the ability to recognize a fallacy in an argument, and the ability to explain the results obtained. The fourth and the last phase was the final report. This phase examined whether the final report presented adhered to the standards of scientific reports, whether the language and ideas were organized appropriately, whether the findings and conclusions agreed with the known theories, and whether the references of consulted resources were clearly indicated.

3.8.2 Physics Achievement Tests

Several researchers strongly recommend achievement tests as effective tools for assessing both conceptual understanding and performance. Westberg et al. (2021) argued that achievement tests are suitable for indicating both the theoretical and performance levels of learning. In this study, the Physics Achievement Test (PAT) items were mainly picked from past KCSE Physics papers that touched on refraction of light, since they were already standardized. Bloom's taxonomy guided the selection of the test items. Given the relatively short instructional period, only the first three

levels of the cognitive domain—knowledge, comprehension, and application—were assessed in the achievement test.

Both pre-test and post-test will contained 30 marks. The tests entailed short-answer questions, those that required statement answers, and a few that required solving problems through calculations. The marking scheme was also prepared by the researcher and validated by a team of physics teachers. Test administration was done by the researcher alongside the corresponding physics teachers, who also assisted in the supervision, marking, scoring, and recording (John, n.d.)

3.8.3 Teachers' Questionnaire

A questionnaire is a form containing questions (Omariba, 2023). It's suitable for collecting data from large populations, groups, or organizations in a consistent way (Omariba, 2023). The current research used a Likert-scale type questionnaire to explore the challenges teachers face when attempting to implement IBL or those that hinder its implementation. The questionnaire had three sections: introduction, likert scale, and a section of open-ended question. The Likert scale section provided a range of statements that described the researcher's perceived challenges in the implementation of the IBL approach in physics instruction. The open-ended section allowed teachers to express their perceived challenges faced while implementing IBL approach in physics instruction.

3.9 Validity and Reliability

3.9.1 Validity

Validity explains the ability of data collection instruments to accurately depict what it was intended to measure (Sürücü & Maslakç, 2020).

3.9.1.1 Content Validity

Sürücü, & Maslakç (2020) define content validity as a form of validity that ensures the expressions in the data collection instruments represent the phenomenon under study. The content area for the study focused on refraction of light. The study ensured content validity by collaborating with physics experts and instructors in picking the test items. A test blueprint that outlined the content aligned with the expected learning

outcomes and maintained a balance among different cognitive levels was developed and use for the test selection.

3.9.1.2 Face Validity

This kind of validity is about how the surface of a data collection instrument reflects the content it is designed to measure; whether it seems relevant and appropriate from the surface for what it is assessing (Sürücü, & Maslakç, 2020). It was upheld by comparing the test to the intended learning outcomes. Both instructors involved in test development and those not involved reviewed the test and provided feedback throughout the process. The pilot study provided data that helped adjust the items to further ensure the test items were valid.

3.9.1.3 Threats to internal validity

Because the research was a multi-group study, selection bias, regression to the mean, and social interactions were the primary potential threats to internal validity (Bhandari, 2023). Random assignment of schools to either the control or the experimental group was used to minimize selection bias and regression to the mean. Additionally, to minimize social desirability, the researcher ensured that an intact physics class in a particular school was assigned to either a control or an experimental group and did not interact with colleagues in the other group (Bhandari, 2023).

3.9.2 Reliability

Reliability explains the ability of the test instrument to produce a consistent result when reused under the same circumstances and with the same respondents ((Sürücü, & Maslakç, 2020). The same tests was administered a second time to the same students used for piloting shortly after the first test to obtain test-retest scores. This is an approved strategy of confirming the reliability of instruments (Sürücü, & Maslakç, 2020). Although Geschwind (2024) criticizes this method for overburdening students and instructors and for potential skewing due to students recalling their previous responses, it remains a reliable approach. To prevent students from influencing the second test, they were not informed about it in advance, making it an unannounced assessment.

To estimate the internal consistency of the test items, Cronbach's coefficient alpha was calculated. An item with an alpha value of .70 or higher was regarded as a reliable item. The formula for calculating Cronbach's alpha was adapted from Sattler (1988), which was appropriate for tests administered at least once. The formula was given by;

$$r_{tt}=(\frac{n}{n\text{-}1})(\frac{s^2\text{-}\sum pq}{s^2})$$

Where r_{tt} was the alpha coefficient, n was the number of items in the test, s^2 was the variance of the whole test, p was the proportion of the respondents who scored the test item correctly, while q represented the proportion that failed the test item.

3.10 Pilot study

Refers to a preliminary investigation done on a smaller scale before the main study, to determine whether the study design is feasible (Sürücü & Maslakç, 2020). The quasi-experiment was piloted in two mixed schools similar to those in which the study was to be conducted, while the Physics Achievement Test and the analytic rubric was piloted in a mixed school, a boys' school, and a girls' school, all similar to those in which the actual study was to be done. Instructors offered feedback on adjusting the rubric to encompass all dimensions, scale labels, and performance standards for each dimension. Moreover, student responses to the test questions indicated how the language used was relevant to them, revealed the ambiguity in wording, and assessed the overall feasibility of the study. All this information was used to refine and improve the research design and the data collection tools. As Omariba (2023) asserts, piloting enhanced pre-testing and adaptation of data collection instruments to the realities in the field, thereby adjusting and aligning where necessary.

3.11 Data collection procedures

The research proposal was approved by Murang'a University of Technology, which, in turn provided an introductory letter to authorize the data collection exercise. Since ethical clearance is now mandatory for all research involving human participants, all postgraduate students must secure ethical approval from their institution's Institutional Scientific and Ethics Research Committee (ISERC). Therefore, the student researcher

acquired the certificate from ISERC to assist with NACOSTI (National Commission for Science, Technology, and Innovation) approval. Once all the necessary certificates were received, the researcher proceeded to the selected secondary schools. To uphold ethical standards, the researcher elaborated on the study purpose to the participants, allowing them to voluntarily decide whether to take part. Those who agreed to participate signed a consent form, giving them the right to voluntarily participate and withdraw from the study when needed, without fear of repercussions. During classroom sessions, all students in an intact classroom were treated equally to prevent discrimination. Participants' identities and responses were kept anonymous and confidential by using pseudonyms. To share findings publicly, the researcher obtained participants' consent. Research assistants were also given manageable workloads to prevent overworking. Any reviewed literature was cited, with references provided to avoid plagiarism.

3.12 Data Presentation and Analysis

The findings of this study were presented using bar graphs and tables. Bar graphs depicted students' achievements before and after the interventions. Also, the performance among the two different levels of inquiry was depicted using bar graphs and tables. Bar graphs provided appealing visual information at a glance, showing which levels of inquiry the students performed very well on and which had the lowest scores.

Both quantitative and qualitative analysis techniques were employed for the study. Descriptive statistics, including mean, median, and standard deviation, Independent Samples t-test, and Paired Sample Statistics were used to analyze objective one. Objective two was analyzed using descriptive statistics, the Wilcoxon Signed-Rank test, and the Mann-Whitney U-test. For objective three, Paired Sample Statistics, ANCOVA, including Levene's Test and Tests of Between-Subjects, and descriptive statistics were used. Finally, objective four was analyzed through thematic analysis for recurring themes, and descriptive statistics were used for mean, frequencies, and standard deviations. Descriptive statistics were employed to describe the nature of the students' scores, while the inferential statistics were used to conclude the effectiveness of the interventions. All the hypotheses were tested at the .05 level of significance. SPSS version 25.0 is the main statistical instrument used for the entire analysis.

3.13 Logistics and ethical considerations

According to Omariba (2023), these are post-field logistics. After obtaining data from the participants using the instruments, the researcher checked for completeness and labeled them with serial numbers. Then, the responses were coded, and the hard copies were securely stored in locked cabinets with access by only the researcher and the research assistants. The computer devices that were used to store the electronic data had passwords known only to the researcher and the assistants. The data was later analyzed and will be discarded as soon as the publication of the study results is done. The identity of the schools was anonymized to prevent accidental disclosure while reporting the findings.

3.13.1 Ethical issue related to research

Ethics in research deals with moral values that guide the researcher when conducting a study (Omariba, 2023). In this study, the researcher avoided plagiarism by acknowledging other people's work through proper citation of their work. Furthermore, the researcher upheld integrity and objectivity by not conducting the research for personal gains, nor did the researcher have negative intentions for the participants' lives. The researcher ensured this by clearly describing the research title and the purpose of the study in both the consent and assent forms to ensure the aim of the study was clear to both the authorities and the respondents before choosing to take part in the study.

3.13.2 Ethical issue on research subjects

The researcher obtained approval from Murang'a University ISERC and then was permitted to collect data by Murang'a University of Technology, NACOSTI, and the school authorities (principals) before engaging with teachers and students. Consent and assent forms were physically distributed to the selected schools, and the principals and students were given time to consider them and completed them afterward. The school principals filled out consent forms on behalf of the parents or guardians of the students. Additionally, students completed assent forms to indicate their agreement to participate in the study. The consent form included the purpose of the study, the duration students were expected to participate, the potential risks and benefits of participation, and assurances of confidentiality and anonymity. A consent statement

that participants acknowledged was also included in the form. The researcher also allowed respondents to voluntarily join the study after assuring them of the confidentiality of their information. Sensitizing teachers about students' right to decide freely whether to participate was done to help prevent coercion, ensuring teachers did not force students to join or not to join the study. Any student who felt coerced by a teacher to participate or abstain was free to report the incident to the principal, the researcher, or their parents or guardians. The researcher collected the consent forms from the schools and stored them in locked cabinets inaccessible to unauthorized persons. No embarrassing questions were asked during the study (Omariba, 2023). When a student disclosed academic problems, they were referred to the dean of studies, who collaborated with the subject teacher to ensure the student received timely help. Students who showed emotional or social problems were referred to the school guidance and counseling authorities for intervention.

Just like any other test, the pretest and the posttest that the researcher used had the potential to cause emotional discomfort among learners. Learners were relieved by being informed that poor performance in the tests would not attract any punishment. There was no punishment for students who declined to take part in the study, nor were they disadvantaged in terms of academic performance, since participation was voluntary. To minimize the risk of teacher turnover, the subject teachers were the research assistants. For the researcher to ensure non-intrusiveness during classroom observations, the classes continued normally without any unique arrangement that could suggest to students that they were being observed. For students who felt uncomfortable during the classroom observations, the researcher positioned himself in a neutral and nonobstrusive area. This ensured the teacher focused on the whole classroom rather than on an individual student. These measures minimized the ‘spotlight effect’. To safeguard participants, anonymity and confidentiality were maintained by the use of codes instead of names on all research instruments. The data was also stored securely in computers with passwords and locked cabinets. Further, all the participants were clearly sensitized that they had a right to leave the study at any time with no explanation or penalty from the researcher. Finally, the researcher was properly enlightened on ethics training and principles that safeguard children. Also, before the research assistants were recruited in the study, they were equally enlightened on such ethics and principles.

3.14 Chapter Summary

The study adopted the pragmatism research philosophy, which prioritizes approaches that best address the research problem over adherence to a single methodological tradition. A convergent parallel mixed-methods research design in which qualitative and quantitative data are collected within the same phase of the study and analyzed separately was adopted in the study. A quasi-experimental Solomon's Four-Group design was used for the quantitative data, in which physics achievement tests and project tests were used as data collection instruments for both the control and the experimental groups. The qualitative data was collected by the use of interviews and teachers' questionnaires. The study was conducted in Suba-South Sub-County, Homa-Bay County, Kenya. The study targeted Form Three students enrolled in the public secondary schools in the sub-county, alongside the teachers in the schools. The researcher employed purposive, stratified, and simple random sampling techniques. Purposive sampling was employed to select four schools that participated in the study: two mixed schools, a girls' school, and a boys' school. Stratified sampling was employed when selecting a school from the three categories: mixed schools, boys' schools, and girls' schools. At least one school was picked from each strata (school categories). Within the selected schools, simple random sampling was employed to select an intact Form Three physics class.

Cochran's (1977) formula was used to calculate the sample size, which was adjusted afterwards using the formula for correction provided by Israel (1992). The formula for stratified sampling was used to calculate the sample size for teachers and students from each school. Analytical rubric was the data collection instrument used to assess and score students projects. For the achievement scores, the students answered physics achievement tests. The study ensured content validity by collaborating with physics experts and instructors in picking the test items. A test blueprint that outlined the content aligned with the expected learning outcomes and maintained a balance among different cognitive levels was developed and use for the test selection. For the test of reliability of the test instruments, the same tests were administered a second time to the same students used for piloting shortly after the first test to obtain test-retest scores. In addition, to estimate the internal consistency of the test items, Cronbach's coefficient alpha was calculated. The research design was piloted in two mixed schools, while the data collection instruments were piloted in three schools.

The research was authorized by Murang'a University of Technology (MUT) Institutional Scientific and Ethics Research Committee (ISERC). The researcher further acquired a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI). The Suba-South Sub-County director of education also gave letter of approval to allow the research take place among the juniors in the sub-county. The study findings were presented using bar graphs and tables. SPSS version 25.0 was used to analyze the data. Descriptive statistics, including mean, median, and standard deviation, Independent Samples t-test, and Paired Sample Statistics were used to analyze objective one. Objective two was analyzed using descriptive statistics, the Wilcoxon Signed-Rank test, and the Mann-Whitney U-test. For objective three, Paired Sample Statistics, ANCOVA, including Levene's Test and Tests of Between-Subjects, and descriptive statistics were used. Finally, objective four was analyzed through thematic analysis for recurring themes, and descriptive statistics were used for mean, frequencies, and standard deviations

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

The findings of the research and their corresponding interpretations are presented in this chapter. The result interpretations are mainly tabulated. The specific objectives that guided the data collection were:

i. To investigate the effect of guided and open inquiry on students' performance in physics projects in Suba South Sub-County.
ii. To investigate the effect of guided and open inquiry on students' physics achievement scores.
iii. To establish the relative predictive strength of guided and open inquiry on students' physics achievement scores and project performance.
iv. To explore the challenges that secondary school teachers face in attempting to implement IBL in physics instruction.

The data analysis aimed at either accepting or rejecting the hypotheses that were in line with the objectives, and to answer the question of the challenges teachers encounter in their attempts to implement IBL.

4.2 Findings

4.2.1 Response Rate

A total of 182 respondents participated in the study. Out of these, 176 were students, and 6 were the respective Physics teachers from the schools. The response rate was 51.70%, which was adequate according to Kunga (2021). A total of 88 students (53 in the experimental group and 35 in the control group) completed a pretest before the intervention began. The control group received instruction through guided inquiry, while the experimental group received instruction through open inquiry for one month. Afterward, all students took a posttest. For the project work, students in both the control and experimental groups were divided into groups. Both groups completed a pretest for project work, and all students took a posttest. The teachers completed a Likert-scale questionnaire to identify the challenges they face in implementing inquiry-based learning.

4.2.2 The effect of guided and open inquiry on students' performance in physics projects

The second objective of the study was to establish the effect that guided and open approaches to inquiry had on students' performance in physics projects. The students conducted their projects in groups, and an analytical rubric was used to score their work during the projects and after the projects to award marks to the reports that they compiled after the projects. Just like in the achievement tests, in the project tests, experimental group 1 and control group 1 did both the pretest and the posttest, while experimental group 2 and control group 2 only did the posttest. The aim of this was to identify whether the pretest had any effect on the scores of the posttest. The descriptive analysis for the project results was as shown in Table 4.1.

Table 4. 1: Descriptive Statistics for Pretest and Posttest Scores

Group	N	M	SD	Min	Max
Experimental Group (Pretest)	12	44.08	5.30	33	52
Experimental Group (Posttest)	12	67.42	5.93	57	80
Control Group (Pretest)	5	28.60	2.88	25	33
Control Group (Posttest)	5	62.20	2.78	59	65

Table 4.1 shows a significant improvement from pretest to posttest in both groups. In the experimental group, the mean score increased from 44.08 with a standard deviation of 5.30 in the pretest to 67.42 with a standard deviation of 5.93 in the post-test. Similarly, in the control group, the mean score increased from 28.60 with a standard deviation of 2.88 in the pretest to 62.20 with a standard deviation of 2.78 in the posttest. These results revealed that both open and guided inquiry had positive effects on the physics projects. The results were consistent with those of Mbata et al. (2025), whose quasi-experiment in Tanzania showed that guided inquiry led to noticeable improvements in practical skills and hands-on activities. Furthermore, Kunga (2021) also found in his study in Kitui, Kenya, that students instructed by IBL strategies outperformed their colleagues in the conventional lecture method in task competencies, whereas DeStefano & Widenhorn (2024) also found that open inquiry positively affected the development of significant project and practical skills in the general experimental design.

Moreover, to determine whether the improvements were statistically significant, the Wilcoxon Signed-Rank Test for Pretest and Posttest Scores was run for both the Table

4 1experimental and the control groups. The Wilcoxon Signed-Rank Test was chosen here due to the small sample sizes for the paired sample t-test. The results were as displayed inTable 4.2.

Table 4. 2:Wilcoxon Signed-Rank Test for Pretest and Posttest Scores

Group	***Z***	***p***	***Decision***
Experimental Group (Pretest vs Posttest)	*-3.06*	*.002*	*Significant*
Control Group (Pretest vs Posttest)	*-2.03*	*.042*	*Significant*

From Table 4.2, the Wilcoxon signed-rank test showed that the improvement experienced in the experimental group was statistically significant (Z = -3.06, p = .002). In addition, the change observed among the control group members was also statistically significant (Z = -2.03, p = .042). Therefore, the study concluded that both guided and open inquiry had positive effects on students' project performance. Additionally, the p-values for both the experimental and control groups, which were .002 and .042, respectively, were lower than the established significance level of .05. As a result, the null hypothesis, that guided and open inquiry have no effect on students' physics achievement scores, was rejected. The column chart depicting the performance in the project tests in both the experimental and control groups were as shown in Figure 4.1 These findings were in agreement with those of Destefano & Widenhorn (2024), who presented that open inquiry improved students' competence in collecting and analyzing data, plotting of graphs, and data presentations.

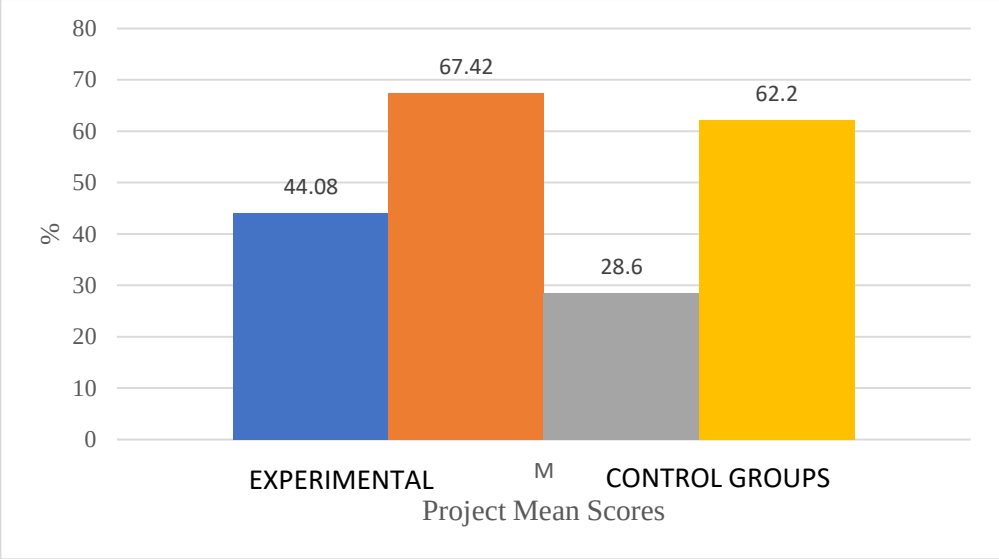


Figure 4. 1: Column graphs for the pretest and posttest project performance mean scores for both the experimental and the control group

Further, to determine whether the pretest had an effect on the posttest performance, a Man-Whitney U test was conducted for any difference in performance in projects between control group 1 and control group 2. The same was repeated for the experimental group 1 and experimental group 2 as shown in Table 4.3.

Table 4. 3: Mann–Whitney U Test Comparing Project Scores Between Control Group 1 and Control

Group	n	Mean Rank	Sum of Ranks
Control Group 1	5	5.90	29.50
Control Group 2	5	5.10	25.50

Statistic	Value
Mann–Whitney U	10.50
Wilcoxon W	25.50
Z	−0.42
p (2-tailed, asymptotic)	.674
Exact p (2-tailed)	.690

The findings in Table 4.3 showed that control group 1 had a slightly higher mean rank of 5.90 than control group 2, which had a mean rank of 5.10. A Man-Whitney U test was done to reveal whether the difference in the mean rank was statistically significant. The findings showed a lack of statistically significant difference between the control group 1 and the control group 2, $U = 10.50, Z = -0.42, P =$

.674 ($two - tailed$). Since the p-value was higher than .05 (p = .674; p>.05), the difference was not statistically significant. Therefore, the pretest among the control group did not have an effect on their performance in the posttest, though the researcher expected that the pretest would lead to improved value on the post-test. Gray (2023) observed that a pretest always influences the posttest. Pretest always, especially in education, familiarizes learners with the content, changes how they pay attention during instruction, and finally influences the nature of their responses in the posttest. Oribhabor (2020) pointed out that in order to determine the effect of activity-based teaching methods on Mathematics scores in Nigerian schools, the researcher had to control the effects of the pretest first. The findings of this study further established that pretests do have effects on posttest scores, even though this wasn't realized in the current study. Therefore, the findings of the study established that the pretest did not have an effect on the posttests among the control group.

The findings were further illustrated as shown in Figures 4.2 and 4.3.

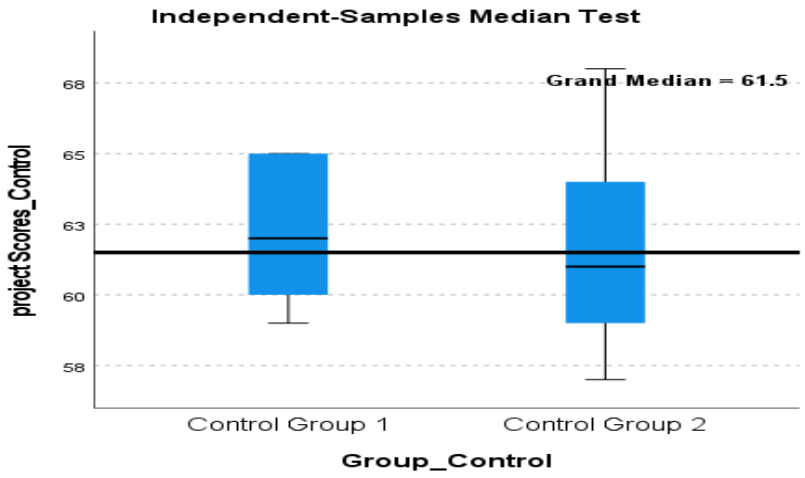


Figure 4. 2: independent-Samples Media Test for the Control groups 1 and 2

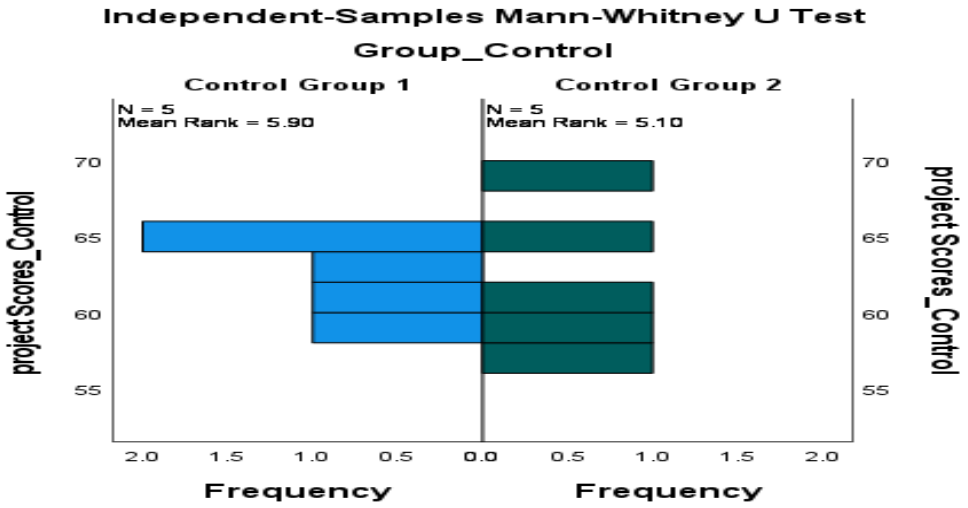


Figure 4. 3: Independent-Samples Mann-Whitney U Test for the control group

Moreover, a similar procedure was repeated for the experimental groups.

Table 4. 4: Mann–Whitney U Test Comparing Project Scores Between Experimental Group 1 and Experimental Group 2

Group	n	Mean Rank	Sum of Ranks
Experimental Group 1	12	8.67	104.00
Experimental Group 2	12	16.33	196.00

Statistic	Value
Mann–Whitney U	26.00
Wilcoxon W	104.00
Z	−2.67
p (2-tailed, asymptotic)	.007
Exact p (2-tailed)	.007

The findings in Table 4.4 showed that there was a statistically significant difference in the score of the two groups, U = 26.00, Z = -2.67, P = .007 (two-tailed). The mean ranking of experimental group two was 16.33, which was considerably higher than that of experimental group one, which was 8.67. This finding indicated that the students in experimental group 2 performed considerably better than those in experimental group 1 in projects. According to this, the pretest had a negative effect on students' performance in the post-test. According to Kim & Willson (2010), “pretests may increase (or decrease, depending on the characteristics of the test)

scores at post-test not only for the same or similar scales but also for dissimilar scales in which the constructs may be completely different". Therefore, the observation experienced, though rare, has some degrees of possibility. Independent-Samples Median Test and Independent-Samples Mann-Whitney U Test for the experimental groups were further used to illustrate the findings diagrammatically as shown in figures 4.4 and 4.5

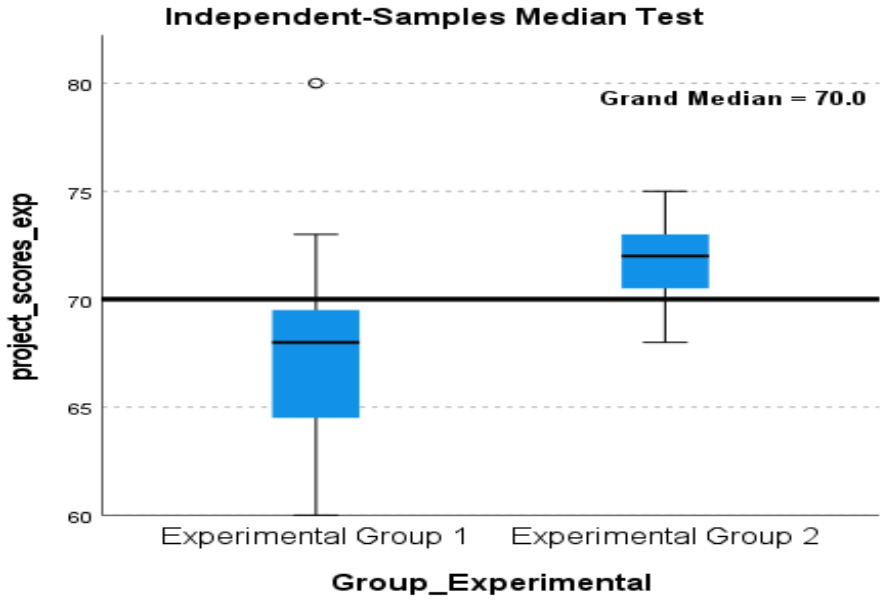


Figure 4. 4: Independent-Samples Mann-Whitney U Test for the control group

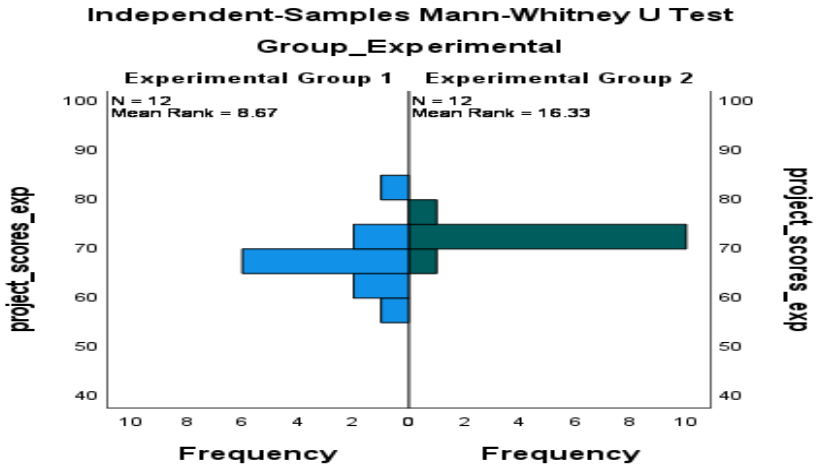


Figure 4. 5: Independent-Samples Mann-Whitney U Test for the experimental group

4.2.3 The effect of guided and open inquiry on students' physics achievement scores

The first objective of the study was to establish the effect that open and guided approaches to inquiry had on physics achievement tests. Before the interventions were implemented, the experimental group one, E1, and the control group one, C1, were subjected to a pretest. This was meant to determine the initial achievement level of the two groups. The descriptive statistics, including the mean and the standard deviation, were determined. The results were as shown in Table 4.5;

Table 4. 5: Descriptive statistics for the pretest

	Category	N	Minimum	Maximum	Mean	Std. deviation	Std. Error Mean
pretest	Experimental group one, E1	53	50	85	68.538	8.2105	1.1278
	Control group one, C1	35	15.0	52.5	32.000	10.3164	2.6637

Table 4.5 shows that the experimental group, which had a mean of 68.538% and a standard deviation of 8.2105, performed much better than the control group, which had a mean score of 32.000% and a standard deviation of 10.3164. The researcher noted that the experimental group 1 was a higher achiever group than the control group 1.

Further, a t-test was carried out as shown in Table 4.6 to determine whether the difference in the students' achievement was statistically significant.

Table 4. 6: The independent Sample t-test for the pretest mean score of the Physics Achievement test for E1

		Levene's Test for Equality of variances		t-test for Equality of Means			95% Confidence Interval of the Difference			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	36.321	.000	5.533	109	.000	17.0757	3.0863	10.9587	23.1927
	Equal variances not assumed			5.696	82.345	.000	17.0757	2.9976	11.1128	23.0385

Table 4.6 shows that the statistical value for the assumption of equal variances was 5.533, while that for the assumption of unequal variances was 5.696, with 109 and 82.345 as their respective degrees of freedom. The significance level obtained was .000, which is lower than the established threshold of 0.05. The study established that the difference in performance between the experimental and the control group was statistically significant, and it was evident that the experimental group was generally a higher-achieving group than the control group at the beginning of the study. The study therefore concluded that the experimental group was a higher achiever than the control group. This was in agreement with the study of El Karkri et al. (2025) who also reports a statistical difference in the baseline between the experimental and control groups

To identify the effect of open inquiry on students' physics achievement tests, a post-test was administered to the experimental group, and results were presented in Table 4.7.

Table 4. 7: Paired sample statistics for the experimental group 1

		Mean	N	Std. Deviation	Std. Error Mean
Pair	PRETEST	68.538	53	8.2105	1.1278
	POST	72.138	53	9.5846	1.3165

The findings in Table 4.7 revealed students' mean score as 68.538% in the pretest, with a standard deviation of 8.2105, while that of the posttest as 72.138%, with a standard deviation of 9.5846. The findings show that the students improved following the implementation of the intervention. Moreover, to determine whether the

improvement was due to the intervention was statistically significant, a paired sample t-test was carried out. The results were tabulated as shown in Table 4.8.

Table 4. 8: Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	**PRETEST-POST**	-2.690	52	.010

The findings in Table 4.8 show a t-value of -2.690, with 52 degrees of freedom and a significance level of .010. Since the significance level obtained was lower than the established level of 0.05, the result of the intervention is statistically significant. The null hypothesis, that open inquiry has no effect on students' physics achievement scores was therefore rejected. That is, the students' physics achievement scores improved significantly after the intervention. The results of this study were in line with several other studies, which had suggested that open inquiry increases students' scores in achievement tests. Cai et al. (2021) had presented that the amount of research that students in open inquiry engage in leads to better acquisition of subject concepts, which translates to improved achievement scores in achievement tests. In addition, Artayasa et al. (2018) also identified that the amount of effort students normally apply in searching literature and formulating their questions and procedures gave them ample time to grasp the concepts better, as reflected in the improved achievement scores in the posttest.

Moreover, to determine the effect guided inquiry had on the students' physics achievement scores, the control group was also administered the posttest, and the results were recorded in Table 4.9

Table 4. 9: Paired Samples Statistics for Control group 1

		Mean	N	Std. Deviation	Std. Error Mean
Pair	**Pretest**	32.000	35	10.3164	2.6637
	Posttest	69.333	35	16.9664	4.3807

Table 4.9 shows that the students' mean score in physics achievement on the pretest was 32.000 with a standard deviation of 10.3164. On the posttest, the mean score

increased to 69.333 with a standard deviation of 16.9664. This revealed that students showed improvement after the guided inquiry intervention. Furthermore, to determine if this improvement was statistically significant, a paired t-test was conducted, and the findings were presented in Table 4.10.

Table 4. 10: Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	PRETEST-POST	-11.914	34	.000

Table 4.10 shows that the t-value for the result was -11.914 with 14 degrees of freedom and a significance level of .000. Since the significance level here was also lower than the established level of 0.05 (0.000 < 0.05), the study concluded that both guided and open inquiry approaches had a significant improvement effect on the students' physics achievement scores. The null hypothesis, that guided and open inquiry has no effect on students' physics achievement scores was rejected. The study findings concurred with those of Mbata et al (2025), who embraced guided inquiry over all other approaches to inquiry for its positive effects on students' achievement scores whereas Antonio & Prudente (2024) pointed out that the scaffolding nature of guided inquiry, while still leaving learners autonomous and responsible for their learning makes it suitable for enhancing achievement scores. Similarly, Abdulmalik Olayinka Anwo et al (2025) had also found similar results when he conducted a study in Nigeria to determine the effect of Vee-Diagram and guided inquiry strategies on Physics achievements among secondary school students. The researcher attributed the notable improvement realized to the high level of students' involvement and engagement in the inquiry process.

Further the study also sought to determine if the pretest had an effect on the achievement on the posttest. To do so, the descriptive statistics and independent t-tests for the achievement scores for both the experimental and control groups were carried out as shown in Tables 4.11 and 4.12.

Table 4. 11: Descriptive Statistics for Achievement Scores by Experimental Group

Group	N	M	SD	SE
Experimental Group 1	53	72.14	9.58	1.32
Experimental Group 2	58	48.10	19.01	2.50

The findings in table 4.11 showed that Experimental Group 1 that had a mean score of 72.14 and a standard deviation of 9.58 scored significantly higher than Experimental Group 2 that had a mean score of 48.10, with a standard deviation of 19.01. Levene's test indicated that the assumption of equal variances was violated, $F(1, 109) = 36.321$, $p < .001$. Therefore, the unequal variances version was used. In addition, an independent sample t-test for achievement was done as shown in Table 4.12

Table 4. 12:Independent Samples t-Test for Achievement Scores

Variable	t	df	p	Mean Difference	95% CI of the Difference
Achievement Scores (equal variances not assumed)	8.52	85.85	< .001	24.04	[18.43, 29.65]

From Table 4.12, an independent samples t-test indicated a statistically significant difference between the two groups, $t = 8.52$, $p < .001$. The mean difference was 24.04 points, and the 95% confidence interval ranged from 18.43 to 29.65.

The effect size was large (Cohen's d = 1.58), revealing that the difference between the two experimental groups was not only statistically significant but also practically significant. The study concluded that the pretest that the students in the experimental group one underwent had a statistically significant effect on the students' achievement in the posttest score. This observation concurred with the findings of El Karkri et al. (2025) in their paper 'The Dual Impact of Pretest Sensitisation and the Cognitive Acceleration Through Science Education Programme in the Solomon Four-Group Design'. They presented that the group that received pretests outperformed their colleagues who were not exposed to pretests. The difference in achievement was further illustrated using a bar graph as shown in Figure 4.6

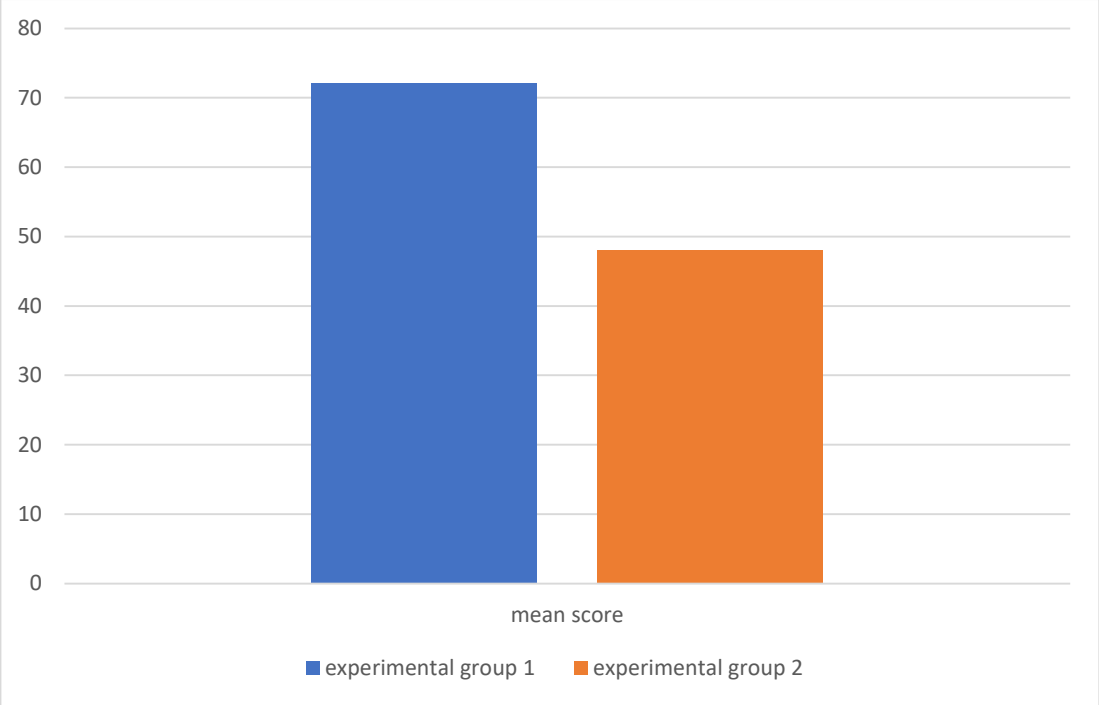


Figure 4. 6: Mean in the posttest scores for experimental groups 1 and 2

Moreover, the effect of the pretest was determined among the control groups. Their results were as shown in table 4.13.

Table 4. 13: Descriptive Statistics for Achievement Scores (Control Groups)

Group	N	M	SD	SE
Control Group 1	35	69.33	16.97	4.38
Control Group 2	30	39.77	11.20	2.99

From Table 4.13, the results showed that control group 1, with a mean score of 69.33 and a standard deviation of 16.97, scored higher than control group 2, which had a mean score of 39.77 and a standard deviation of 11.20. An independent t-test was run to determine whether the difference in the achievement scores was significant. The results were as displayed in Table 4.14

Table 4. 14: Independent Samples t-Test for Achievement Scores (Control Groups)

Variable	t	df	p	Mean Difference	95% CI of the Difference
Achievement Scores (equal variances assumed)	5.49	63	< .001	29.56	[18.52, 40.60]

The Levene's test was not significant, F(1, 27) = 1.98, p = .171; therefore, the equal variances assumption row was reported. The findings in Table 15 of an independent samples t-test indicated a statistically significant difference between the two control groups, t(27) = 5.49, p < .001. The mean difference was 29.56 points, and the 95% confidence interval ranged from 18.52 to 40.60. The study established that the effect size was extremely large (Cohen's d = 2.04), indicating a very big practical difference between the two control groups. The study established that Control Group 1 performed much better than Control Group 2 in terms of achievement scores. Additionally, the effect of the pretest is experienced. The group that did the pretest outperformed those that did only the posttest. This was consistent with the finding of El Karkri et al. (2025), that a pretest always has improvement effects on the posttest achievements. Therefore, the conclusion that the pretest made effect on the posttest achievement is justifiable. This was further plotted in bar graphs as shown in figure 4.7.

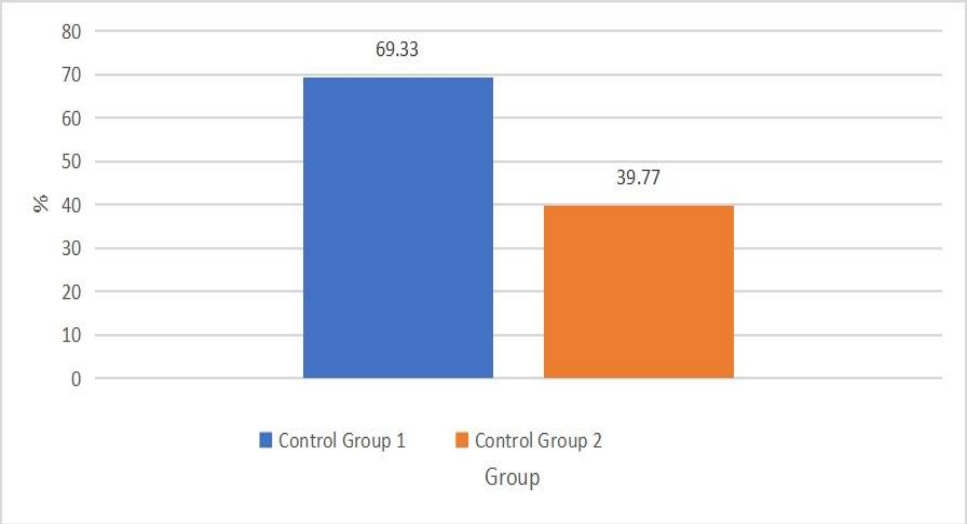


Figure 4. 7: Mean in the posttest scores for control groups 1 and 2

4.2.4 Determining the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and physics project performance

The third objective of the researcher was to determine the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and project performance.

To determine the comparative effect of guided and open inquiry in enhancing students' physics achievement scores , descriptive statistics for the experimental and control

groups were sought, and a group statistic was also computed as shown in table 4.15 and table 4.16.

Table 4. 15: Paired sample statistics for the experimental group 1

		Mean	N	Std. Deviation	Std. Error Mean
Pair	**PRETEST**	68.538	53	8.2105	1.1278
	POST	72.138	53	9.5846	1.3165

Table 4. 16: Paired Samples Statistics for Control group 1

		Mean	N	Std. Deviation	Std. Error Mean
Pair	**Pretest**	32.000	35	10.3164	2.6637
	Posttest	69.333	35	16.9664	4.3807

From the findings in tables 4.15 and 4.16, the posttest mean score for the experimental group 1 was 72.138, with a standard deviation of 9.5846, which was instructed by open inquiry was higher than that of the control group which was 69.333, with a standard deviation of 16.9664, which was instructed by guided inquiry. Since the experimental group had performed better than the control group in the pretest at the beginning of the study, concluding that the group with the highest posttest score experienced the greatest improvement due to the intervention would be unreliable. Instead, the mean gains were computed between the pretest and the posttest for both groups. For the experimental group, the improvement was from 68.538 in the pretest to 72.138 in the posttest, recording a mean gain of +3.6, whereas the control group's scores improved from 32.000 in the pretest, to 69.333 in the posttest. The mean gain for the control group was therefore +37.333. Thus, the control group had a much larger mean gain than the experimental group. To control for pretest sensitization and adjust for baseline imbalances between the groups, an ANCOVA was run on the pretest and posttest scores for the two groups, as shown in Tables 4.17 and 4.18.

Table 4. 17: Levene's Test for Equality of Error Variances

F	df1	df2	Sig.
.662	1	83	.419

The findings in Table 4.17 showed that the assumption of homogeneity of variances was satisfied since the level of significance (P = .419) was bigger than the threshold of .05. Further, ANCOVA test was run to control for the baseline imbalances as shown in Table 4.18.

Table 4. 18: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6538.295	2	3269.148	39.701	.000	.562
Intercept	1752.787	1	1752.787	21.286	.000	.256
Pretest	1925.402	1	1925.402	23.382	.000	.274
Group	137.401	1	137.401	1.669	.201	.026
Error	5105.385	82	82.345			
Total	306751.909	85				
Corrected Total	11643.680	84				

The findings in Table 4.18 showed that the difference between the mean scores for the experimental and the control groups was not statistically significant (P = .201), and hence the difference observed in the mean scores was attributed to the original imbalances experienced during the pretest, and not due to the interventions. This result concurs with the findings of Gao & Matsouaka (2024), who presented that sometimes improvements can be due to baseline imbalances if not properly adjusted.. Therefore, basing our conclusion on the large mean gain that was witnessed in the control group, guided inquiry had a larger improvement effect in the achievement scores than open inquiry, and hence guided inquiry is a stronger predictor of physics achievement scores than guided inquiry.

Further, to determine which between guided and open inquiry was a stronger predictor of students' performance in physics projects, the descriptive statistics were sought, as shown in Table 4.19

Table 4. 19: Descriptive Statistics for Pretest and Posttest Scores

Group	N	M	SD	Min	Max
Experimental Group (Pretest)	12	44.08	5.30	33	52
Experimental Group (Posttest)	12	67.42	5.93	57	80
Control Group (Pretest)	5	28.60	2.88	25	33
Control Group (Posttest)	5	62.20	2.78	59	65

The findings in Table 4.19 depict that the experimental group performed better than the control group in the pretest at the beginning of the study. And so, being that the experimental group performed better than the control group in the posttest is not enough to justify that the difference was due to the different interventions. Moreover, to give a valid conclusion, the mean gains for the two groups were sought. The experimental group improved from a mean score of 44.08 in the pretest to 67.42 in the posttest, gaining a score of +23.34. The control group, on the other hand, improved from 28.60 in the pretest to 62.20 in the posttest. This gave a mean gain of +33.60. The results showed that the mean gains for the control group (+33.60) were higher than those of the experimental group (+23.34). This finding concurs with that of Mbata et al (2025), who concluded by emphasizing guided inquiry for its ability to develop practical skills among learners

Additionally, to control the effects of the pretest sensitization and adjust for the baseline imbalances at the beginning of the study, ANCOVA test was run as shown in Table 4.20 and Table 4.21.

Table 4. 20: Levene's Test for Equality of Error Variances for the project performance

F	df1	df2	Sig.
1.151	1	15	.300

The assumption of homogeneity of variances was met as indicated by the large p-value (P = .300) compared with the established .05 value. This finding showed that the variances of the two groups, the experimental and the control, were similar. The ANCOVA test for differences between the control and experimental groups, after adjusting for the baseline effect and pretest sensitization, is shown in Table 4.21.

Table 4. 21: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	96.284	2	48.142	1.614	.234	.187
Intercept	1037.159	1	1037.159	34.781	.000	.713
Pretest	.236	1	.236	.008	.930	.001
Group	23.512	1	23.512	.788	.390	.053
Error	417.481	14	29.820			
Total	74302.000	17				
Corrected Total	513.765	16				

The findings in Table 4.21 show that the difference between the experimental and the control group was not statistically significant (P = .390). In light of the large mean gain in the control group compared to the experimental group, the study concluded that the experimental group's higher performance was due to initial imbalances at the beginning of the study, and that the control group improved more than the experimental group. Hence, the guided inquiry used among the control group was a stronger predictor of students' physics performance than the open inquiry used among the experimental group students. Therefore, the null hypothesis, that there is no statistically significant difference in predictive strength of guided and open inquiry in enhancing students' physics achievement scores and project performance, was rejected at .05 significance level. These findings concur with the findings of Mbata et al. (2025), who presented that guided inquiry led to better development of practical and hands-on skills than open inquiry. Additionally, Abdulmalik Olayinka Anwo et al. (2025) also presented that guided inquiry had a higher improvement effect on students' project performances than other approaches of inquiry.

4.2.5 Challenges that secondary school teachers face in attempting to implement IBL in physics instruction.

The fourth objective of the study was to explore the challenges secondary school teachers face in their attempts to implement IBL in physics instruction. A Likert-scale questionnaire was used to survey the level to which the physics teachers concurred with some statements of the challenges in a scale of 1 (strongly disagree) to 4(strongly agree). A section of the questionnaire sought open ended responses where teachers

expressed their views that they felt were not covered in the statements. Since the responses were coded, descriptive statistics was run to help analyze the challenges. Frequencies of the responses and the mean score were used to determine the level of teachers' agreement with the given statements. In line with the Likert-scale used, a lower mean score indicated a weak agreement, while a higher mean score indicated a strong agreement. The statements describing the challenges and their frequencies were as shown in Table 4.22.

Table 4. 22: Descriptive Statistics for the Challenges in implementation of IBL

	N	Minimum	Maximum	Mean	Std. Deviation
It is difficult for me to design inquiry-based physics lessons	6	1	2	1.17	.408
I lack the confidence to facilitate student-led investigations	6	1	2	1.17	.408
It is hard to assess students' achievement levels in IBL Physics classes	6	1	2	1.33	.516
The culture of my school discourages collaboration and teamwork required in IBL	6	1	2	1.50	.548
The students are demotivated to engage in inquiry activities	6	1	3	1.67	.816
My knowledge of IBL strategies suitable for physics is limited	6	1	2	1.67	.516
Colleagues are reluctant to offer support when using IBL	6	1	2	1.67	.516
Managing students' behaviors during IBL lessons is so challenging	6	1	3	1.83	.753
My school has obsolete equipment that can no longer support IBL	6	1	3	1.83	.983
The school administration does not give priority to IBL strategies in Physics	6	1	4	2.00	1.265
The material and equipment required by IBL are either unavailable or expensive	6	1	3	2.17	.753
IBL presents a workload beyond what I can manage for a single lesson	6	1	3	2.17	.753
The demand of the secondary school physics curriculum contradicts the requirements of IBL	6	1	4	2.17	.983
The standardized examination and curriculum are too rigid and don't allow IBL	6	1	4	2.17	1.169
There are limited laboratory facilities in the school where I work	6	1	3	2.33	.816
Instructional materials that support IBL are insufficient in my school	6	1	3	2.33	.816
The large class sizes in my institution hinder the implementation of IBL	6	1	4	2.33	1.366
The time allocated for a given physics lesson is not enough to complete all the inquiry activities	6	1	4	2.33	1.211
Students have limited prior knowledge of conducting inquiries	6	2	4	2.83	.753
Students prefer being told the solutions to problems rather than discovering them on their own	6	2	4	3.00	.632
The rush to complete the syllabus discourages the implementation of IBL	6	1	4	3.00	1.265

The allocated time per term is limited for adequate syllabus coverage under IBL strategies	6	2	4	3.17	.753
IBL requires more lesson preparation time, which is usually not available	6	2	4	3.33	1.033
Poor internet connectivity and access to digital resources in my school hinder IBL usage	6	1	4	3.33	1.211
Valid N (listwise)	**6**				

Table 4.22 shows the descriptive statistics, including the mean and the standard deviation of the challenges teachers face in their attempts to implement IBL in Physics instructions. The challenges that had a mean score of 3.00 and above were regarded as the most severe ones in the implementation of IBL in secondary school physics instruction. The findings established that the teachers recognized that from the most pronounced challenge to the least were poor internet connectivity and access to digital resources in their schools with a mean of 3.33 and a standard deviation of 1.211, the more preparation time required by IBL which is not usually available with a mean of 3.33 and standard deviation of 1.033, short time allocation per term which can't allow syllabus coverage under IBL which had a mean of 3.17 and a standard deviation of .753, the rush to complete the syllabus with a mean of 3.00 and a standard deviation of 1.265, and that students prefer being told the problem solutions rather than inquiring on their own with a mean of 3.00 and a standard deviation of .632. These findings agree with the findings of Torres et al (2022) in the study on the contribution of inquiry-based physics teaching and learning in initial teacher training: challenges and opportunities.

The challenges that had a mean score of 2.00 to 2.83 were treated as moderately agreed upon. They included students' limited prior knowledge on conducting inquiries with a mean of 2.83, short time allocation per physics lesson, which isn't enough for full inquiries which had a mean of 2.33, large class sizes which hinder inquiry class design with a mean of 2.33, insufficient instructional materials and limited laboratory facilities with a mean of 2.33, standardized examinations and rigid secondary physics curriculum that hinders inquiry with a mean of 2.17, IBL workload being too much for a single class, and school administrations not prioritizing IBL strategies which had a mean of 2.17. Most of these challenges were similar to those identified by earlier challenges. For instance, Letina (2021) identified time constraints for IBL preparation and coverage of an extensive secondary physics syllabus, organizational barriers,

which included reluctance by administrators to support IBL, students' characteristics and competencies, inadequate textbooks, the high costs of materials and equipment for inquiry, and lack of motivation among learners to conduct inquiries. Four out of six teachers who participated in this study also identified that learners preferred being told solutions to problems rather than inquiring by themselves. The findings also concur with the findings of Mosley & Connolly (2021) in their study titled 'The use of inquiry-based learning in public administration education: challenges and opportunities in the contest of internationalization'.

The teachers either strongly disagreed or disagreed with the statements of the challenges that recorded a mean score of less than 2.00, as shown in Tables 4.23 to 4.26.

Table 4. 23: My knowledge of IBL strategies suitable for Physics is limited

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly disagree	2	33.3	33.3	33.3
	Disagree	4	66.7	66.7	100.0
	Total	6	100.0	100.0	

Table 4. 24: It is difficult for me to design inquiry-based physics lessons

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly disagree	5	83.3	83.3	83.3
	Disagree	1	16.7	16.7	100.0
	Total	6	100.0	100.0	

Table 4. 25: I lack the confidence to facilitate student-led investigations

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly disagree	5	83.3	83.3	83.3
	Disagree	1	16.7	16.7	100.0
	Total	6	100.0	100.0	

Table 4. 26: It is hard to assess students' achievement levels in IBL physics classes

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly disagree	4	66.7	66.7	66.7
	Disagree	2	33.3	33.3	100.0
	Total	6	100.0	100.0	

The findings in the frequency Table 4.23 showed that 33.3% of the teachers strongly disagreed, while 66.7% disagreed with the statement that they had limited knowledge of IBL strategies suitable for Physics. In Table 4.24, 83.3% of the teachers strongly disagreed, while 16.7% disagreed with the statement that it was difficult for them to design inquiry-based physics lessons. In Table 4.25 as well, 83.3% of the teachers strongly disagreed, while 16.7% disagreed with the statement that they lacked the confidence to facilitate student-led investigations. The findings in Table 4.26 revealed that 66.7% of the teachers strongly disagreed, while 33.3% disagreed with the statement that it was hard for them to assess students' achievement levels in IBL physics classes. From the foregoing findings, the study concluded that the knowledge of facilitating IBL classes and assessing their achievement in such classes is no longer a challenge to the teachers. Additionally, the questionnaire provided the teachers with open-ended questions that allowed them to respond in their own words. T1 pointed out that, "*Most students in local schools have a culture that views physics as a subject for a special group of students, and therefore, implementing IBL in such classes becomes a challenge. Digital illiteracy and language barriers also hinder the implementation of IBL in teaching sciences (Physics).*" T2 mentioned that, "*There are limited resources to diversify the use of IBL in teaching physics, and the available time is insufficient to complete all inquiry activities in a lesson*". According to T3, "*Students love copying from others'*. T4 noted that "*IBL takes a lot of time, and students find it hard to come up with solutions*". T5 did not answer the open-ended question, while T6 mentioned that *"students are not ready to move to inquiry-based learning since it is a new approach for them"*. These findings concurred with the findings of Mosley & Connolly (2021), who also identified that IBL was so demanding to learners who were used to structured teacher-based instructions, and hence appeared

to be less satisfied by the unfamiliar nature of the tasks they were required to engage in.

For a long time, limited knowledge of IBL strategies, difficulty in designing inquiry-based physics classes, and challenges in assessing students' achievements in inquiry classes were major hurdles that impeded the implementation of IBL in secondary schools. For example, Assuah et al. (2022) noted that implementing IBL in West African countries remained difficult due to inadequate teacher training and uncertainty about which inquiry approach best suits secondary classes. Mrosso et al. (2025) also revealed that countries in southern Africa were hesitant to adopt IBL, even after demonstrating its effectiveness, because teachers lacked sufficient understanding of how to properly execute IBL. Further, the teachers who participated in this study responded that, because of the rollout of the new CBC curriculum, they had attended several workshops and in-service training sessions on contemporary instructional methods, including IBL, and therefore felt well prepared to conduct IBL classes.

The study, therefore, concluded that the major challenges that teachers face while attempting to implement IBL are time constraints, poor internet connectivity, and the digital divide, students' preference for being given solutions rather than searching on their own. These findings concurred with the findings of Torres et al (2022), Letina (2021), and Mosley & Connolly (2021). The findings also showed that teachers are well-equipped in terms of pedagogical understanding on how to conduct IBL classes due to the in-service training they have undergone.

4.3 Chapter Summary

The study had a total of 182 respondents, which comprised 176 students and 6 teachers. The first objective aimed to determine the effect that guided and open approaches to inquiry had on students' performance in physics projects. The students conducted their projects in groups, and an analytical rubric was used to score their work during the projects and after the projects to award marks to the reports that they compiled after the projects. The students were grouped into either a control or experimental group. Experimental group 1 and control group 1 did both the pretest and the posttest, while experimental group 2 and control group 2 only did the posttest. This was done to determine whether pretest had effect on the posttests. The results

showed that both the experimental and the control group, which were instructed by open and guided inquiry approaches respectively had significant improvement after the interventions. These results revealed that both open and guided inquiry had positive effects on the physics projects. Therefore, the null hypothesis that guided and open inquiry had no significant improvement effect on students' physics project performance was therefore rejected. In addition, the Wilcoxon Signed-Rank Test revealed that the improvement due to both the interventions was statistically significant. Mann-Whitney U Test Comparing Project Scores showed that the pretest did not have significant effect on the posttest among the control groups, while it had a negative effect among the experimental groups. While determining the effect of open and guided approaches of inquiry in enhancing students' physics achievements, a paired sample test for the experimental group 1 showed that open inquiry had improvement effect on the achievement scores. The null hypothesis, that open inquiry has no effect on students' physics achievement scores was therefore rejected. Similarly, a paired sample test for the control group 1 revealed that guided inquiry also had an improvement effect on the physics achievement scores among the students. The null hypothesis that guided inquiry has no significant effect on students' physics achievement scores was therefore rejected.

When determining the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and physics project performance, guided inquiry proved to be of much improvement effect on both physics project and the achievement scores. Finally, the conspicuous challenges identified to face the implementation of IBL were poor internet connectivity and access to digital resources in schools, the more preparation time required by IBL which is not usually available, short time allocation per term which can't allow syllabus coverage under IBL, the rush to complete the syllabus, and that students prefer being told the problem solutions rather than inquiring on their own.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the findings

The summary of the findings is given per objective, the corresponding hypothesis, and the research question.

Objective one sought to investigate the effect of guided and open inquiry on students' performance in physics projects. The results showed that both guided and open inquiry had an improvement effect on students' performance in physics projects. The Wilcoxon Signed-rank test was carried out in both groups to determine whether the improvements were statistically significant. The test showed that the improvement experienced in the experimental group was statistically significant. Similarly, the test among the control group, in which guided inquiry was implemented, also indicated the improvement was statistically significant. Since the p-value for both the experimental and the control group was lower than the established significance level of .05, the hypothesis, guided and open inquiry have no effect on students' performance in physics projects, was rejected.

The Mann-Whitney U Test, which was conducted to assess the effect of the pretest on the posttest, showed no statistically significant difference between control group 1 and control group 2. The p-value was higher than .05, hence the difference was not statistically significant. Therefore, the pretest among the control group did not have any effect on the posttest. Among the experimental group, the pretest had a decreasing effect on the posttest.

The second objective sought to investigate the effect of guided and open inquiry on students' physics achievement scores. Students in both guided and open inquiry improved in their physics achievement scores after the interventions. A paired sample t-test was run to determine whether the improvement was statistically significant. The results showed that the improvement was statistically significant since the p-value obtained was lower than the .05 threshold. Here, too, a paired sample t-test was done to determine if the improvement was statistically significant. The p-value obtained

here was lower than the established .05; therefore, the improvement was statistically significant.

An independent samples t-test was carried out to identify if the pretest had any effect on the posttest. The results revealed that the experimental group 1, which took both pretest and posttest, had a higher mean score than the experimental group 2, which only took the posttest. An independent samples t-test showed that the difference between the mean scores of the two groups was statistically significant. The large effect size indicated that the difference in the mean scores between the two experimental groups was not only statistically significant but also practically significant. The results also showed that control group 1, which took both the pretest and the posttest, scored significantly higher in their post-test compared to control group 2, which took only the post-test. An independent samples t-test indicated a statistically significant difference between the two control groups. The large effect size (Cohen's d) indicated a big practical difference between the two control groups.

The third objective aimed to determine the comparative effect of guided and open inquiry in enhancing students' physics achievement scores and project performance. Both the interventions, open and guided inquiry, showed an improvement effect on the students' physics achievement scores, but guided inquiry proved to be enhancing physics achievements than open inquiry. When the mean gains were sought for both the groups, that of the control group in which guided inquiry was used, was higher than that of the experimental group, in which open inquiry was used. In addition, since the experimental group registered a higher mean score in the pretest and the posttest than the control group, ANCOVA was run to control the effect of the pretest variable and the baseline imbalances. Levene's test for equality of variances was not statistically significant. Therefore, the condition of homogeneity of variances was met. ANCOVA results showed that the mean differences between the two groups were not statistically significant, indicating that the higher posttest mean score of the experimental group was due to the baseline imbalances observed in the pretest, and not due to the different intervention used.

Findings revealed that both guided and open inquiry enhanced students' performance in physics projects, but that guided inquiry had improvement effect than open inquiry. Though both the experimental group and the control group witnessed an improvement

effect in their mean scores after the interventions, the control group improved with a greater mean gain than the experimental group. Levene's test showed that the condition of variance homogeneity was met. The test of the between-subjects effects showed that the difference in the scores between the experimental and the control group was not statistically significant. Therefore, in the light of the mean gains, guided inquiry had a higher improvement effect on physics project performance than open inquiry.

The fourth objective on the other hand sought to explore the challenges that secondary school teachers face in attempting to implement IBL in physics instruction. According to how the teachers responded to the Likert-scale questionnaire, there were challenges they regarded as the most severe, others were moderately hindering IBL implementation, while some of the statements in the questionnaire were no longer regarded as challenges at all. The challenges that had the highest mean scores were poor internet connectivity and access to digital resources within the schools, the more preparation time needed by IBL, which is usually not available, short time allocation per term which cannot allow adequate syllabus coverage under IBL strategies, the rush to complete the syllabus, and the students preference of being told the solutions to the problems rather than discovering on their own.

The challenges that the teachers moderately agreed upon were: students' limited prior knowledge on conducting inquiries, short time allocation per lesson which is not enough for all inquiries for a single lesson, large class sizes that hinders inquiry class designs, insufficient instructional materials, limited laboratory equipment, standardized examinations and rigid secondary physics curriculum, too much workload IBL presents for a single class, and the issue of school administrations not prioritizing IBL strategies. The study also revealed that limited teachers' knowledge on IBL strategies, difficulty in designing inquiry-based physics classes, and challenges in assessing students' achievements under IBL, which originally hindered IBL implementation, are no longer hindrances in the attempts to implement IBL. The teachers said that they have been given adequate in-service training and hence are well equipped for not only IBL, but also other contemporary instructional strategies.

5.2 Conclusion

Based on the study findings, the researcher concluded that both open and guided approaches to inquiry improve students' physics achievement scores. Both open and guided approaches to inquiry also improve students' physics project performance. Guided inquiry is a stronger predictor of physics achievement scores and project performance than open inquiry. Students prefer being told solutions rather than searching for them through inquiry. Poor internet connectivity, the digital divide, and time constraints are the major challenges facing the implementation of IBL. Secondary school teachers no longer struggle with the knowledge of designing, conducting, and assessing learners in IBL classes.

5.3 Recommendations

5.3.1 Recommendations for interventions

Since several studies have shown the effectiveness of IBL in enhancing students' achievement scores and performance in project and practical work, the following recommendations were made to enhance integrated science instruction, since physics, which was the center of this study, is now incorporated in the integrated science in the new CBE curriculum.

i. The school administrations should prioritize IBL strategies of instruction and give the necessary support toward their implementation.
ii. The learners should receive scaffolding on the inquiry strategies until they readily adopt the strategies.
iii. Extra time should be given for additional tutorials to supplement the normal classes. This will give enough time for the teachers to adequately prepare for the IBL lessons and reduce the rush to complete the syllabus.
iv. The standardized examination policy should be reviewed to give room for varied ways of assessment relevant to IBL strategies.
v. The KICD under the new CBE should abolish the rigid secondary school curriculum to allow students to inquire and not be teacher-centered.

5.3.2 Recommendation for further study

Since the researcher did not manage to fully exploit all the dimensions of IBL as an instructional strategy, the following recommendations were made for future research:

i. The effect of IBL on students' engagement in integrated science lessons
ii. The students' attitudes toward IBL as a contemporary instructional strategy
iii. How the effect of IBL on Integrated Science project performance and achievement scores varies with class levels
iv. Whether IBL has an improvement effect on achievement scores and project performance in other learning areas like languages and Mathematics.

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APPENDICES

Appendix 1: Research Tools

Physics achievement test on Refraction of light

Pre-test

1) The figure below represents a ray of light striking a glass prism that has a critical angle of 42^0

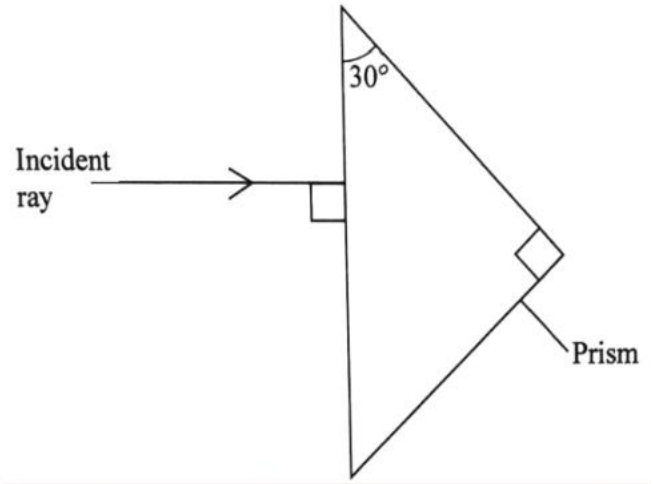
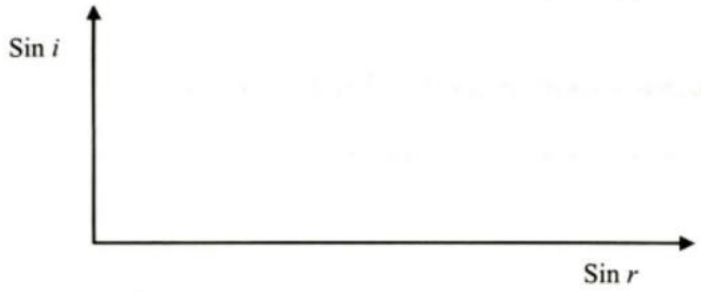


Figure 6

Complete the path of the ray to show it emerges from the (2marks)

2) A student observed a rainbow when it was raining and the sun was shining. Explain how the rainbow was formed (2mks)
3) State the reason why sound waves get refracted up into the atmosphere during hot days (1mk)
4) Form Three students experimented to determine how the angle of incidence i of a ray of light striking the air-glass interface related to the angle of refraction r formed in the glass medium.

    a) Sketch on the axes below the graph of sin i against sin r of he experimental values found (2marks)



b) Explain how the students could determine the refractive index of the glass from the graph above (1mark) (22)

5) Explain how the speed of water waves in a ripple tank varies as it moves to a deep end from the shallow end (2marks)

Given that a light ray from glass to air forms a critical angle of 42, calculate the refractive index of the glass (3marks)

A metallic object is situated 15 cm below the surface of an ice block. If the ice block has a refractive index of 1.32, find the depth from the surface of the block where the metal object appears to be (3marks)

6) Find the angle of refraction for a ray that travels from air to a liquid of refractive index of 1.36, given that the angle of incidence at the interface is 30 (2marks)
7) The figure below shows an air-glass interface

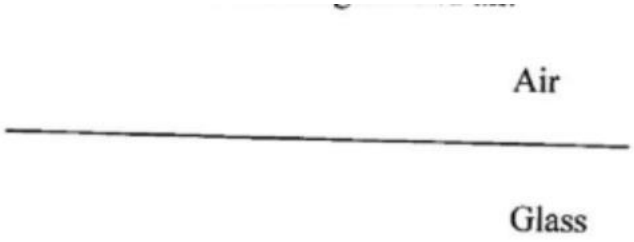


Figure 5

Sketch on the diagram the position of the critical angle (3marks)

8) The diagram below represents a ray striking a right-angled glass prism at a right angle to the face AB. Given that the prism has a refractive index of 1.62,

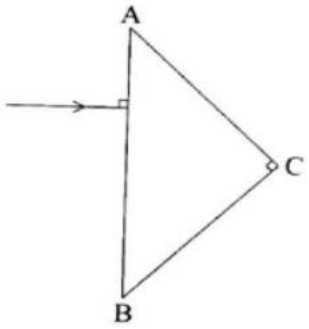


Figure 6

a. Find the critical angle of the material of the glass (3marks)

b. State any two applications of prisms (2marks)

If a pen at the base of a container holding glycerine of refractive index 1.47 appears to be 6.8 cm below the surface of the glycerine, what is the actual depth of the glycerine in the container? (3marks)

The figure below shows a triangular glass prism ABC with a light ray striking it at a right angle on side AB. Given that the glass has a refractive index of 42, sketch the path followed by the ray after leaving side AC (2marks)

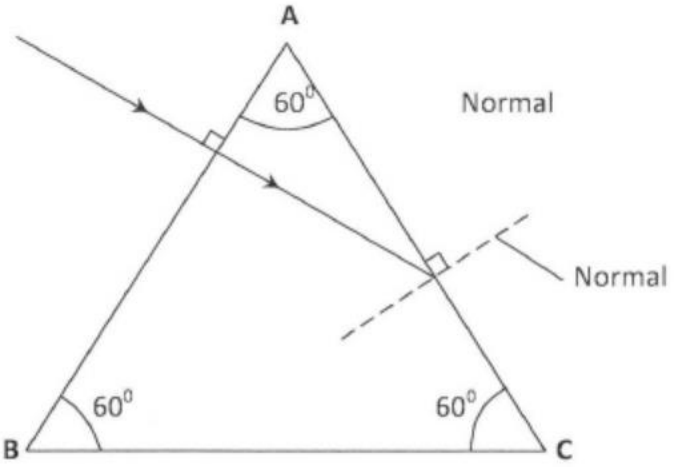


Figure 3

Post-test

1. An object O is placed at the bottom-center of a liquid-containing beaker, 40cm below the surface. If the observer above the beaker sees the image of the object at point X, calculate the refractive index of the liquid.

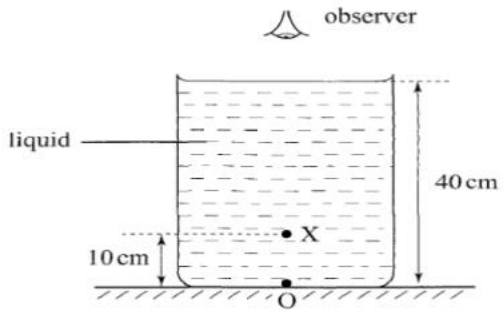


Figure 5

2. Figure 4 below shows two parallel rays striking side PQ of the right-angled glass prism at right angles. If the critical angel of the prism is 42, complete the paths of the rays as they emerge out of the prism

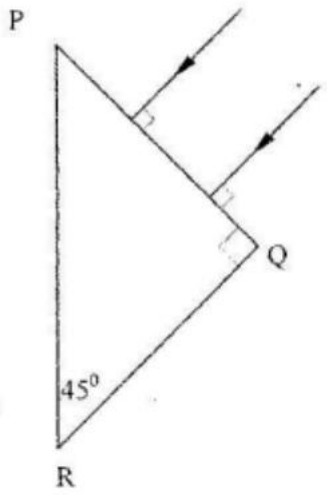


Figure 7

3. (a) Define the term critical angle as used in refraction of light (1mark)

(b) Derive an expression relating the critical angle of any medium and its refractive index (3marks)

4. The layers of water, oil, and glass are parallel to each other, and a ray of light strikes the air-water interface at an incidence angle of 60 and travels through them successively in that order until it gets into the air again. Given that the refractive indices of water, oil, and glass are $\frac{4}{3}$, $\frac{6}{5}$, and $\frac{3}{2}$, respectively,

a. Sketch a diagram to show how the light tay travels through the layers until it emerges into air again (3marks)

b. Calculate:

i. The refraction angle in the water (3marks)

ii. The incidence angle at the boundary of oil and glass (2marks)

5 a) Define total internal reflection as used in refraction of light (1mark)

b) What are the conditions for the occurrence of the total internal reflection? (2marks)

c) Explain two effects of the total internal reflection (4marks)

6. With the aid of diagrams, describe two applications of total internal reflection (6marks)

Analytical rubric for assessing students' project performance

		Weighing				
Phases of the project	**Criteria**	**Little merit (1)**	**Below average (2)**	**Average performance (3)**	**Above average (4)**	**Excellent (5)**
Planning stage (20%)	Fundamental knowledge of the topic	Shows little/no knowledge; Major misconceptions	Limited knowledge; vague, incomplete ideas	Adequate knowledge; some gaps remain	Good knowledge; mostly correct and relevant	Thorough and detailed knowledge; accurate, clear understanding
	Ability to propose a plan for the project	No clear plan; unrealistic or irrelevant	The plan is weak; it is missing important steps	Plan is workable, but lacks detail/clarity	Plan is clear, logical, and mostly complete	Excellent, detailed, creative, and well-structured plan
	Willingness to ask questions and ability to answer questions from others	Never asks/answers questions; passive	Rarely asks/answers; responses are weak	Sometimes asks/answers; limited confidence	Often asks/ answers; shows interest and effort	Actively and confidently asks insightful questions and gives thoughtful answers
	Capacity for original thought	No originality; ideas copied from others	Limited originality; little initiative	Some evidence of originality; ideas simple	Shows creativity and independent thought	Highly original, creative ideas; strong initiative and innovation

The experimental stage (30%)	Possession of appropriate manipulative skills	Cannot handle apparatus; frequent mistakes	Struggle with apparatus; limited accuracy	Handles apparatus adequately with some errors	Confident, mostly accurate handling of apparatus	Skillful, precise, and confident handling of apparatus at all times
	Co-operation with other members of the group	Group members cannot co-operate at all; disrupted collaboration	Cooperates poorly; reluctant to share tasks	Moderate cooperation; uneven participation	Good cooperation. Each group member contributes fairly to the group	Excellent cooperation; encourages and supports all members
	Willingness to consult the teacher and accept help from other learners	Does not consult; ignores advice	Rarely consults; resists help	Sometimes consults; accepts some guidance	Often consults; willing to accept help	Proactively seeks guidance; values input from others
	Ability to work effectively and independently	Cannot work without constant supervision	Relies heavily on others; rarely independent	Works independently at times with some errors	Works independently and effectively most of the time	Consistently works independently, effectively, and accurately
	Attitude to practical work and economical use of material	Careless, wasteful, and unsafe	Shows limited care; wastes some materials	Adequate care; some wastage/errors	Careful, economical, and responsible	Very careful, safe, and economical; models best practices
	Skill in observation and	Makes no useful observati	Few observations:	Records basic observat	Records clear, mostly	Excellent, precise, systematic

	data recording	on; poor recording	incomplete/inaccurate records	ion; some errors	accurate data	observation and well-organized records
The post-laboratory stage (25%)	Ability to present experimental results clearly	Results missing or unreadable	Results unclear; poor organization	Results presented adequately; some errors	Results presented clearly with minor flaws	Results presented excellently; clear, accurate, well-organized
	Capacity for logical and analytical results clearly	No analysis; illogical or irrelevant	Limited logic; weak analysis	Basic analysis; some valid reasoning	Sound analysis; logical explanations	Excellent, deep analysis; strong logical reasoning
	Ability to detect fallacies in arguments	Cannot identify errors; accepts all claims	Rarely notices errors; weak justification	Sometimes detects errors; explanation limited	Often detects errors; provides sound reasoning	Consistently detects and explains fallacies with clear justification
	Willingness and ability to try to solve problems raised by others	Shows no interest in helping peers	Reluctant to help; little effort	Offers some help when asked	Willingly helps others; provides useful suggestions	Actively helps solve problems with insightful, effective solutions.
	Ability to offer explanations for different results obtained	No explanation attempted	Weak, vague explanations; mostly incorrect	Provides basic explanation; partly correct	Provides clear, mostly correct explanations	Gives excellent, accurate explanation with significant insight
Final report (25%)	Organization of ideas, language, depth of treatme	Disorganized; poor language; incomplete	Limited organization; many errors; shallow content.	Adequate organization; moderate depth;	Well-organized; clear language; good depth; neat	Excellent organization; polished language; comprehensive, deep, neat report

	nt, scope, and neatness			some errors	presentation	
	General layout of the report	Unable to design scientific reporting of findings; doesn't employ data presentation tools; results disconnected from theoretical framework	Develops a disorganized scientific report, with incomplete parts; result presentation tools (e.g., graphs and charts) are inaccurately drawn	Report adheres to most of the scientific standards, with limited errors; data presentation tools are correctly framed		The report is developed according to scientific standards, with clear, logical, and accurate diagrams/graphs/charts and conclusions that agree with the theoretical framework
	References of consulted sources	No references given	Few/irrelevant references; incorrect format	Some relevant references, limited accuracy	Several relevant, properly formatted references	Many high-quality, relevant sources; correctly formatted and well-integrated

Adapted from KLB PHYSICS BK 3 tr guide

Teachers' Questionnaire

Teachers' Challenges in Implementing Inquiry-Based Learning (IBL) in Physics Education

Section A: Introduction

This questionnaire is designed to help the researcher explore the challenges you face as a teacher when trying to implement IBL in physics instruction. Your identity will remain anonymous, and responses will be kept confidential. The responses will be used solely for academic purposes and not for any other reason.

Section B: Background Information

Please tick (✓) or fill in where appropriate.

1. Gender: ☐ Male ☐ Female

2. Age: ☐ Below 30 ☐ 30–39 ☐ 40–49 ☐ 50 and above

3. Teaching experience: ☐ Less than 5 years ☐ 5–10 years ☐ 11–20 years ☐ Over 20 years

4. Highest academic qualification: ☐ Diploma ☐ Bachelor's Degree ☐ Master's Degree ☐ PhD

5. Have you ever received training in Inquiry-Based Learning (IBL)? ☐ Yes ☐ No

Section C: Challenges in the implementation of IBL in physics instruction

Instruction: Use the given key to express the level to which you agree or disagree with the provided statements. 1. Strongly Disagree (SD), 2. Disagree (D), 3. Agree (A), 4. Strongly Agree (SA)

- **Pedagogical and knowledge-related challenges**

S/N	Statement	1 (SD)	2 (D)	3 (A)	4 (SA)
1	My knowledge of IBL strategies suitable for physics is limited				
2	It is difficult for me to design inquiry-based physics lessons				
3	I find it hard to assess students' achievement levels in IBL physics classes				
4	I lack the confidence to facilitate student-led investigations				
5	The demands of the secondary school physics curriculum contradict the requirement of IBL				

❖ **Resource and Infrastructure challenges**

S/N	Statement	1 (SD)	2 (D)	3 (A)	4 (SA)
1	There are limited laboratory facilities in the school where I work				
2	Instructional materials that support IBL are insufficient in my school				
3	The material and equipment required by IBL are either unavailable or expensive				
4	My school has obsolete equipment that can no longer support IBL				
5	Poor internet connectivity and access to digital resources in my school hinders IBL usage				

❖ **Administrative and Institutional Challenges**

S/N	Statement	1 (SD)	2 (D)	3 (A)	4 (SA)
1	The school administration doesn't give priority to IBL strategies in physics classes				
2	Colleagues are reluctant to offer support when using IBL				
3	The large class sizes in my institution hinder the implementation of IBL				
4	The culture of my school discourages collaboration and teamwork as required by IBL				
5	The standardized examination and curriculum are too rigid and don't allow IBL				

❖ **Student-related challenges**

S/N	Statement	1 (SD)	2 (D)	3 (A)	4(SA)
1	Students are demotivated to engage in inquiry activities				
2	Students find doing independent or group discoveries difficult				
3	Students have limited prior knowledge of conducting inquiries				
4	Students prefer being told the solutions to problems rather than discovering them on their own				
5	Managing student behaviors during IBL sessions is so challenging				

❖ **Time and workload-related challenges**

S/N	Statement	1 (SD)	2 (D)	3 (A)	4(SA)
1	IBL requires more lesson preparation time, which is usually not available				
2	The allocated time per term is limited for adequate syllabus coverage under the IBL strategy				
3	The time allocated for a given physics lesson is not enough to complete all the inquiry activities for the lesson				
4	IBL presents a workload beyond what I can manage for a single class				
5	The rush for syllabus completion discourages the implementation of IBL.				

Section D: Open-Ended Question

❖ Use your own words to describe any other challenges faced in the process of implementing Inquiry-Based Learning in teaching physics

Projects for assessment

a) Design a project using locally available materials to illustrate the refraction of light.
b) Design a project to determine the refractive index of water, paraffin, and oil
c) Students to design projects using locally available materials to illustrate the dispersion of white light into seven colors
d) Designing projects to illustrate total internal reflection and the determination of the critical angle of a semi-circular glass block.

Appendix 2: Secondary schools in Suba South Sub-County

1. PSS1
2. PSS2
3. PSS3
4. PSS4
5. PSS5
6. PSS6
7. PSS7
8. PSS8
9. PSS9
10. PSS10
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36. PSS36
37. PSS37
38. PSS38
39. PSS39

Appendix 3: Principal's Consent Form and Students' Assent Form

Title of the study: Effect of Guided and Open approaches of Inquiry-Based Learning on Students' Academic Achievement in Physics in Secondary Schools in Suba South Sub-County, Kenya

Purpose of the study: To investigate the effect of guided and open approaches to IBL on students' achievement in Physics.

Procedures involved:

After attaining permission from the relevant authorities (NACOSTI & ISERC), the researcher, alongside the subject teacher, will give your students a pretest to determine their current level of understanding of the topic of discussion, refraction of light. The students will then be instructed by the approach of instruction under study for a period of one month, and then be given a posttest to determine the change in achievement, if any, before and after the intervention. The subject teachers will also be asked to fill out a questionnaire, which will give data concerning the challenges that teachers often encounter in the process of implementing Inquiry-Based Learning approaches.

Expected duration.

The students, with their teachers, will be asked to participate in the research for a maximum of one month. The study will be done during the normal physics lessons as stipulated in the school timetable to avoid interference with the normal routine of the school.

Voluntary participation and right to withdraw

The participation of the learners and the physics teachers will be voluntary, and they will be enlightened on their right to withdraw at any point that they feel like doing so. The recruitment of the student respondents will be totally free from any kind of coercion from the researcher or the research assistants. The principal investigator asks that you affirm this to the students. Additionally, their right of withdrawal from the study will be reaffirmed to them y the researcher before the study commences.

Risks and benefits

This study poses no foreseeable risks to learners, beyond the normal anxieties associated with a typical classroom environment, such as the anticipation of a test or examination.

Participating in the study will have direct benefits for your students, as they will be the primary subjects who reveal the effectiveness of the instructional approach to teaching refraction of light and other physics topics, as will be extrapolated from the study results. The teachers will adjust their instructional approaches accordingly for maximum physics achievement, as will be suggested by the study findings.

Confidentiality and data protection measures

Any information provided by the students will be confidential and only handled by the researcher and the research assistants. The data collected from students will be kept under locked cabinets for printed documents, while soft copies will be kept in computers with passwords only known by the authorized persons. During the publication of the results from this study, the identity of the students, the teachers, and the school's name, including any information that could lead to a hint to the participants and the school identity, will be kept anonymous through the use of codes instead of actual names.

Contact information for the PI and ISERC.

The principal investigator (PI) in this study is Robbinson Maina, of ID no. 38838515, of Tel no. 0746826565, and email address robbisonmaina@gmail.com. The ethical standards in the study have been confirmed by the Institutional Scientific Ethical Review Committee (ISERC); email iserc@mut.ac.ke, Murang'a University of Technology.

Signing the form below allows your students and physics teachers to take part in the study.

If you accept our request to allow your school to take part in this study, then confirm to us by signing the form below. The researcher will pick them after one week. Failure to fill them will be understood as the school's commitment to other activities, which won't allow room for our study.

Principal's consent

Having read and understood the aim of the study, I, _____ allow Form Three physics students and the physics teachers of _____ secondary school to take part in the study described above.

_____ _____

Signature Date

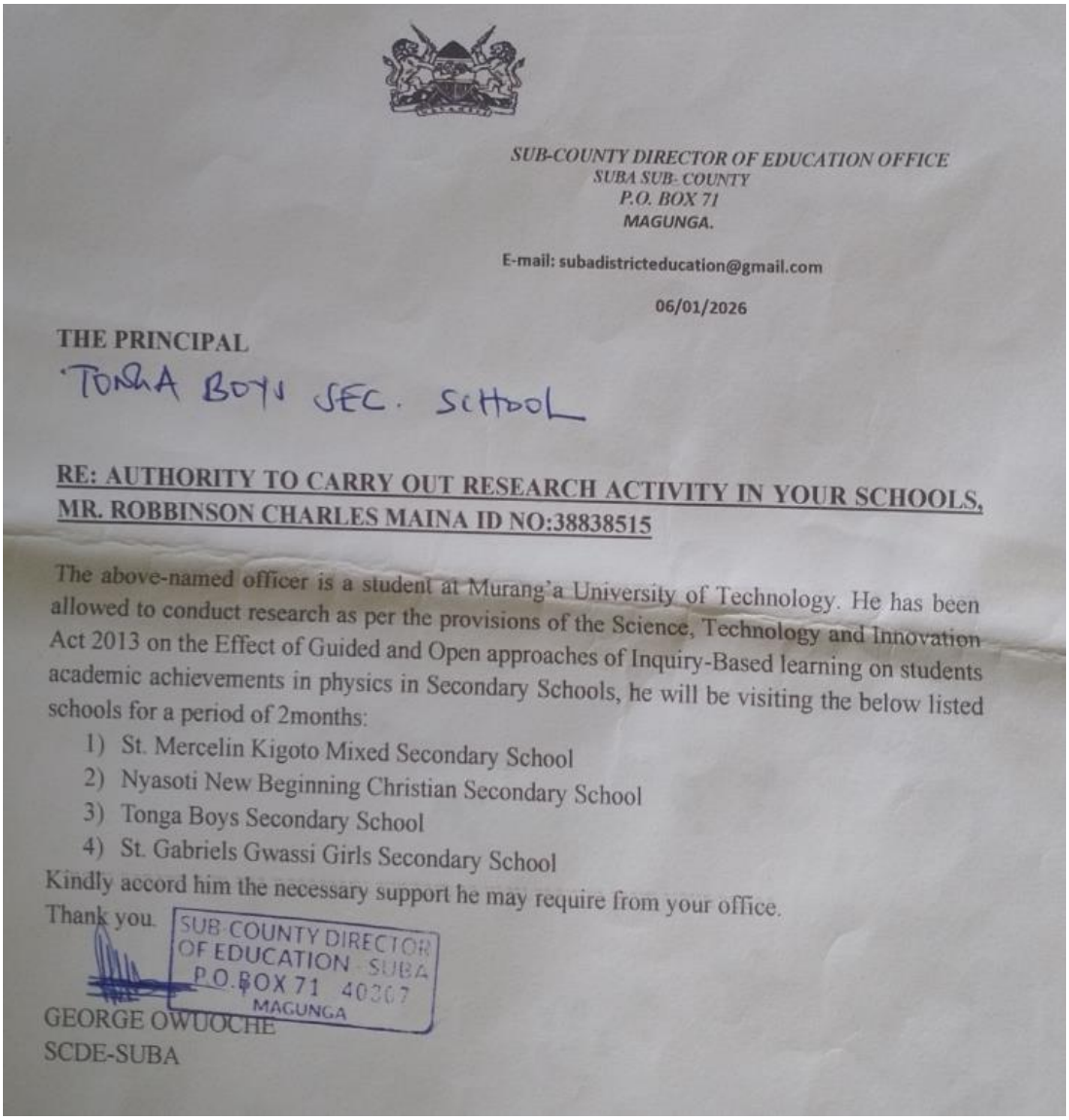
Student's Assent

I,_____, having understood my rights to voluntarily join and withdraw my participation from he study described above, without fear of any repercussion, agree to participate in the study.

Signature:_____

Date:_____

Appendix 4: Authorization from the sub-county's Director of Education



SUB-COUNTY DIRECTOR OF EDUCATION OFFICE
SUBA SUB- COUNTY
P.O. BOX 71
MAGUNGA.

E-mail: subadistricteducation@gmail.com

06/01/2026

THE PRINCIPAL
'TONGA BOYS SEC. SCHOOL

RE: AUTHORITY TO CARRY OUT RESEARCH ACTIVITY IN YOUR SCHOOLS, MR. ROBBINSON CHARLES MAINA ID NO:38838515

The above-named officer is a student at Murang'a University of Technology. He has been allowed to conduct research as per the provisions of the Science, Technology and Innovation Act 2013 on the Effect of Guided and Open approaches of Inquiry-Based learning on students academic achievements in physics in Secondary Schools, he will be visiting the below listed schools for a period of 2months:

1) St. Mercelin Kigoto Mixed Secondary School
2) Nyasoti New Beginning Christian Secondary School
3) Tonga Boys Secondary School
4) St. Gabriels Gwassi Girls Secondary School

Kindly accord him the necessary support he may require from your office.

Thank you.

SUB-COUNTY DIRECTOR OF EDUCATION - SUBA P.O.BOX 71 40307 MAGUNGA

GEORGE OWUOCHE
SCDE-SUBA

Appendix 5: Research permit from NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 245977

Date of Issue: 17/December/2025

RESEARCH LICENSE



This is to Certify that Mr.. Robbinson Charles Maina of Murang'a University of Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Homabay on the topic: EFFECT OF GUIDED AND OPEN APPROACHES OF INQUIRY-BASED LEARNING ON STUDENTS' ACADEMIC ACHIEVEMENT IN PHYSICS IN SECONDARY SCHOOLS IN SUBA SOUTH SUB-COUNTY, KENYA for the period ending : 17/December/2026.

License No: NACOSTI/P/25/4182921

245977

Applicant Identification Number

Ag. Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix 6: ISERC Approval

OFFICE OF INSTITUTIONAL SCIENTIFIC ETHICS REVIEW COMMITTEE
MURANG'A UNIVERSITY OF TECHNOLOGY
Website: www.mut.ac.ke ; Email: iserc@mut.ac.ke

Ref: **MUT-ISERC/A/015** 24TH NOVEMBER 2025

ROBBINSON MAINA
Reg. No: EH401/5216/2024

Dear Robbinson,

RE: Effect of guided and open approaches of inquiry-based learning on students' academic achievement in Physics in secondary schools in Suba South Sub-County, Kenya (P015/11/2025)

This is to inform you that the Murang'a University of Technology Institutional Scientific Ethics Review Committee (MUT-ISERC) has reviewed and **approved** your above research proposal. The approval period is **24th November 2025 to 23rd November 2026.**

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc) are submitted for review and approval by MUT-ISERC before implementation.
c) Any adverse events (death, life-threatening problems) whether related or unrelated to the study, must be reported to the MUT-ISERC within 72 hours of occurrence.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to MUT-ISERC within 72 hours.
e) Clearance of export of biological specimens must be obtained from relevant institutions.
f) Submission of Progress reports at a regular interval, at least every 6 months.
g) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal).*
h) Submission of an *executive summary* report within 90 days upon completion of the study to MUT-ISERC.

Prior to commencing your study, you will be expected to obtain a research license from NACOSTI, and other clearances as applicable.

Yours sincerely

Dr. D. Otieno, PhD
Chairman, Murang'a University of Technology ISERC

INSTITUTIONAL SCIENTIFIC ETHICS REVIEW COMMITTEE
MURANG'A UNIVERSITY OF TECHNOLOGY
24 NOV 2025
CHAIRMAN

Appendix 7: Publication

This thesis has produced the following publication:

Maina, R., Omariba, A. & Mbacho, N. (2026). Comparing the Relative Predictive Strength of Guided and Open Inquiry in Enhancing Students' Physics Achievement Scores and Physics Project Performance. East African Journal of Education Studies, 9(2), 788-800. https://doi.org/10.37284/eajes.9.2.5144