



# EVALUATING THE EFFECTIVENESS OF INQUIRY-BASED LEARNING FOR ENHANCING CONCEPTUAL UNDERSTANDING IN SENIOR HIGH SCHOOL PHYSICS

<sup>1</sup>Frank Aduo, <sup>2</sup>Raphael Yao Vorleto, <sup>3</sup>Michael Tabbey-Appiah, <sup>4</sup>Charles Mussah

<sup>1</sup>University of Education, Winneba, <sup>2</sup>E. P. College of Education, Bimbilla, <sup>3</sup>University of Education, Winneba, <sup>4</sup>University of Education, Winneba

Corresponding Author: [aduofrank1@gmail.com](mailto:aduofrank1@gmail.com)

**Abstract :** The study employs a qualitative case study methodology to offer an in-depth investigation of the adoption and effects of Inquiry-Based Learning (IBL) within selected senior high school physics classrooms. This research design is particularly suited for exploring complex educational phenomena within their natural settings, providing holistic and contextually rich understandings that quantitative methods typically overlook. The case study approach allows for the intensive examination of specific instances—such as particular schools, teachers, and student groups—thereby yielding detailed, nuanced accounts of how IBL influences conceptual understanding and instructional practices. By integrating multiple data sources including interviews, observations, document analyses, and concept assessments, the methodology supports triangulation that enhances validity and depth. This iterative, flexible design enables continuous refinement of the inquiry and deeper engagement with emerging themes, ensuring comprehensive capture of participants' lived realities.

**Keywords** - Inquiry-Based Learning, Conceptual Understanding, High School Physics, Qualitative Case Study, Science Education

## INTRODUCTION

Physics is fundamental to the advancement of scientific literacy and technological innovation. Nevertheless, many senior high school students face significant challenges in comprehending its abstract and complex concepts. The primary aim of education at all levels is to facilitate meaningful learning that transforms the learner, fostering self-directed and lifelong learners capable of acquiring, integrating, and applying knowledge to solve real-world problems. Teaching methods, encompassing instructional strategies, organization, subject matter delivery, and the use of teaching resources, play a pivotal role in attaining these educational objectives (Shymansky & Kyle, 2008).

In numerous educational contexts, particularly within developing countries, physics instruction remains predominantly teacher-centered and reliant on rote memorization practices (Abrahams & Reiss, 2012). Such traditional approaches inadequately support students' conceptual understanding, often resulting in persistent misconceptions and suboptimal academic achievement in physics (Bao & Redish, 2006). In contrast, Inquiry-Based Learning (IBL), grounded in constructivist pedagogy, offers a student-centered instructional framework

that promotes active engagement through questioning, exploration, experimentation, and problem-solving. By facilitating students' experiential and reflective interaction with content, IBL supports the construction of robust conceptual frameworks essential for mastering complex physics phenomena (Hmelo-Silver et al., 2007; Spronken-Smith, 2012).

However, learners enter the classroom with pre-existing conceptions about natural phenomena, which frequently conflict with scientifically accepted explanations (Khandagale & Chavan, 2017). The difficulty of physics concepts, combined with learners' misconceptions, poses significant instructional challenges. Furthermore, in many rural and under-resourced educational settings, teachers often lack adequate professional development, teaching materials, and pedagogical support necessary for effective IBL implementation (Buabeng et al., 2020). This deficit exacerbates students' disengagement, undermines academic performance, and diminishes sustained interest in physics.

Despite broad advocacy for IBL as a transformative pedagogical approach, evidence regarding its efficacy in enhancing conceptual understanding within authentic classroom contexts—especially in developing country settings—remains limited. Moreover, the experiential realities of teachers and learners undertaking IBL in such contexts have not been sufficiently documented. This study, therefore, aims to investigate the impact of inquiry-based learning on senior high school students' conceptual understanding in physics and to explore the perspectives and experiences of both teachers and students engaged in IBL pedagogical environments. The findings have the potential to inform instructional practices that bridge the persistent divide between student performance and meaningful physics comprehension.

### **Purpose of the Study**

The purpose of this study is to investigate the effects of inquiry-based learning on senior high school students' understanding of key physics concepts and to analyze the perceptions and experiences of both teachers and students as they engage with IBL within authentic classroom settings. This study seeks to provide a comprehensive understanding of how IBL influences conceptual comprehension and to explore the practical challenges and benefits encountered during its implementation.

### **Significance of the study**

This study holds significant value as it addresses a critical gap in physics education by examining the role of Inquiry-Based Learning (IBL) in enhancing students' conceptual understanding—an area where traditional teaching methods have often fallen short. By focusing on senior high school physics, the research contributes to advancing pedagogical practices that promote deeper learning, critical thinking, and problem-solving skills essential for scientific literacy and innovation. Furthermore, the exploration of teachers' and students' experiences with IBL offers practical insights into the implementation challenges and facilitators within under-resourced or rural educational contexts. The findings are expected to inform curriculum developers, educators, and policymakers aiming to improve science instruction quality, ultimately supporting the development of self-directed learners capable of applying physics knowledge to real-world problems. This research thus has the potential to impact not only academic achievement but also long-term student engagement and interest in science careers.

### **Objectives of the Study**

1. To investigate how high school physics teachers implement IBL strategies in the classroom.
2. To explore students' experiences with IBL in learning physics concepts.
3. To examine the extent to which IBL improves students' conceptual understanding of physics.
4. To identify the challenges and enabling factors in implementing IBL in high school physics classrooms.

### **Research Questions**

1. How do physics teachers implement inquiry-based learning strategies in their classrooms?
2. How do students experience IBL in learning high school physics concepts?
3. What is the impact of IBL on students' conceptual understanding of physics?
4. What challenges and supports influence the effective implementation of IBL in physics education?

## Review of Related Literature

### Conceptual understanding of physics

Research on conceptual learning in physics has spanned over six decades, drawing significant influence from foundational theories by Jean Piaget and Lev Vygotsky. Piaget's theory of personal constructivism emphasizes how learners actively build conceptual knowledge through cognitive processes such as assimilation and accommodation (Piaget et al., 1952). This approach highlights the interplay between new information and existing knowledge structures (Ausubel, 1968), alongside criteria for meaningful learning, including intelligibility, plausibility, and usefulness (Posner et al., 1982). Conceptual understanding in science is characterized not just by the ability to memorize facts, but by the capacity to explain, interpret, and apply scientific concepts effectively (Redish, 1994). In physics, misconceptions are prevalent due to the subject's inherently abstract and counterintuitive concepts (Bao & Redish, 2006). Traditional instructional methods often prioritize procedural knowledge and rote learning, resulting in fragmented and superficial comprehension rather than cohesive conceptual grasp.

### Inquiry-Based Learning

Inquiry-Based Learning (IBL) is a learner-centered pedagogy driven by students' curiosity and their own questions. It emphasizes active participation in the learning process, encouraging students to engage in self-directed inquiry and develop lifelong research skills (Spronken-Smith, 2012). This approach aligns with Benjamin Franklin's famous assertion from the 18th century that deeper understanding arises from involvement rather than passive reception—"Tell me and I forget, show me and I remember, involve me and I understand." The roots of inquiry-based learning extend back to ancient philosophy, with figures such as Confucius and Socrates exemplifying early inquiry methods. In the 17th century, philosophers like Spinoza argued that knowledge is created through the manipulation of ideas rather than simple fact transmission. The pedagogical foundation of IBL was largely shaped by John Dewey (1859–1952), an American educator who championed 'learning by doing.' Dewey's influence led to broader adoption of IBL in schools and higher education institutions starting in the 1970s (Spronken-Smith, 2012).

IBL facilitates learners in constructing their own understanding of complex phenomena in the natural and human world. Core features common to many IBL models include learner-centered investigations of relevant issues or problems, active discovery and reflection, and thoughtful engagement with challenging content. A curriculum grounded in IBL encourages students to connect new knowledge with prior understanding, use deliberate cognitive strategies, and actively monitor and evaluate their learning processes. In science and mathematics education, IBL involves students exploring, experimenting, and problem-solving to grasp concepts and phenomena (Breen et al., 2023).

IBL's instructional approach involves students posing questions, collecting and analyzing data, drawing conclusions, and sharing findings, mirroring authentic scientific inquiry. Influential cognitive theorists such as Bruner (1961) and constructivists including Vygotsky emphasize that knowledge is most effectively learned through active construction rather than passive reception.

IBL is firmly grounded in constructivist theories, particularly those advanced by Piaget and Vygotsky, which highlight learning as an active process shaped by experience and social interaction (Fosnot, 2013).

In the Sub-Saharan African context, research highlights systemic challenges limiting the effective implementation of IBL. Many science teachers have limited exposure to inquiry pedagogy during their training and face barriers including overcrowded classrooms, inadequate laboratory resources, and curricula heavily focused on examinations (Kibirige et al., 2014). Studies from Ghana reveal a significant mismatch between the aspirational aims of the curriculum and on-the-ground teaching practices, particularly in rural and underserved schools, where teachers often revert to traditional lecture methods due to insufficient professional development and resource constraints (Buabeng et al., 2020).

### Inquiry-Based Learning in Teaching and Learning of Physics

Yuliati, Hapsari, Nurhidayah, and Halim (2018) investigated the effects of inquiry-based learning within STEM education on students' scientific literacy and conceptual understanding in physics. Their study focused on 10th-grade senior high school students learning Newton's laws. Results demonstrated that students exposed to inquiry-based learning achieved significantly higher conceptual understanding compared to those taught through traditional methods. Moreover, students with strong conceptual understanding consistently exhibited better scientific literacy. The study found a significant positive correlation between conceptual achievement and scientific literacy, highlighting those students who thoroughly grasp scientific principles are better able to explain phenomena in detail. Conversely, students with weaker conceptual understanding tended to rely on intuitive or

verbal reasoning when solving problems. These findings underscore the beneficial role of inquiry-based learning in enhancing both conceptual mastery and scientific literacy (Yuliati et al., 2018).

Similarly, Choudhary (2016) examined the impact of inquiry-based instruction on secondary school students' attitudes and academic achievement in physics. Initial pre-test results showed no significant differences in attitude or achievement between experimental and control groups. However, after sixteen weeks of inquiry-based instructional intervention, students in the experimental group achieved significantly higher academic performance than those in the control group. This improvement was attributed to the hands-on, investigative nature of inquiry learning, which afforded students opportunities to observe phenomena, collect data, and interpret results actively (Choudhary, 2016).

### **Comparison of the Inquiry-based learning and Conventional instruction**

In recent years, inquiry-based instruction has been increasingly integrated into college science laboratories and recognized for its positive impact on student learning outcomes. Students participating in inquiry-based labs have shown modest but statistically significant improvements in scientific literacy and process skills compared to those engaged in traditional, recipe-style laboratory activities. However, implementing an inquiry-driven laboratory curriculum demands considerable investment, not only in developing new curricular materials but also in providing specialized training for instructors to effectively facilitate the shift from conventional teaching methods to inquiry-based approaches. Furthermore, students often resist inquiry instruction initially, as it requires them to engage with scientific problems at a more complex and analytical level. Consequently, relying solely on student evaluations to assess the effectiveness of inquiry-based courses can be misleading. Although inquiry lab students tend to rate their experiences lower on course evaluations compared to their counterparts in traditional labs, they exhibit a more accurate self-assessment of their scientific abilities and demonstrate a greater appreciation for their learning achievements (Gormally, Brickman, Hallar, & Armstrong, 2009).

### **Structuring Students' Conceptual Knowledge**

The role of prior knowledge in learning has been a central theme in many theoretical discussions about knowledge acquisition, particularly focusing on how existing knowledge is reorganized during the learning process. Rumelhart and Norman (1978) conceptualize knowledge as structured in schemata and identify three types of learning based on the degree of modification to these schemata: accretion, tuning, and restructuring. Accretion involves adding new facts without altering existing schemas, tuning implies adjusting current knowledge structures, and restructuring entails a more profound transformation of those structures, with increasing levels of cognitive effort required from the learner.

Posner, Strike, Hewson, and Gerzog (1982) further elaborate on how conceptual change occurs, differentiating between assimilation—where learners incorporate new information into their existing knowledge—and accommodation, which requires the replacement or significant reorganization of central concepts. They propose a model of conceptual change rooted in the philosophy of science, outlining specific conditions that must be met for effective accommodation of new scientific ideas.

Linn (1986) draws an analogy between students' prior knowledge and Lakatos' philosophy of science, describing knowledge as composed of a "hard core" of fundamental ideas that learners are generally resistant to changing, and a "protective belt" of more flexible subordinate ideas that students are more willing to adjust when faced with new evidence. This framework helps explain the persistence of misconceptions despite conflicting information.

Carey (1986) discusses two levels of knowledge restructuring: weak and strong. Weak restructuring involves mainly forming new relationships among existing concepts, whereas strong restructuring requires fundamental changes to core concepts themselves as well as the range of phenomena those concepts explain. Carey argues that mastering formal physics often necessitates strong restructuring of learners' prior knowledge.

Together, the research discussed indicates that constructing accurate and deep understanding in formal physics requires significant restructuring of existing knowledge schemata, a process which is neither straightforward nor rapid. It demands substantial instructional time and carefully designed educational activities.

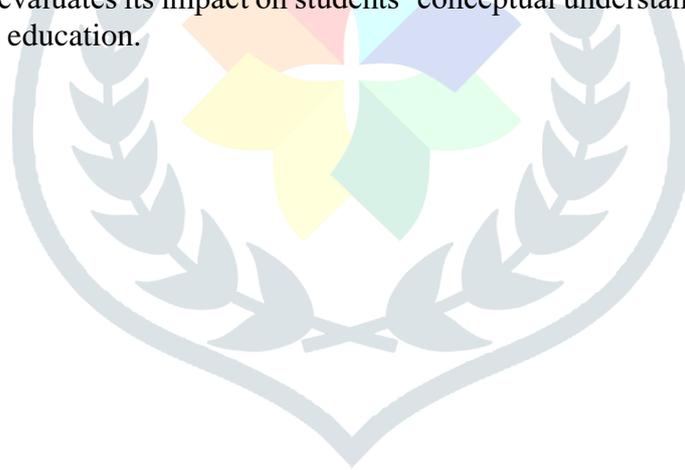
In response, instructional strategies have increasingly focused on integrating students' prior knowledge rather than disregarding it (Champagne, Klopfer, & Gunstone, 1982; Clement, Brown, & Zietsman, 1989). More recent research emphasizes the importance of identifying and documenting intermediate knowledge states during learning (Brown & Clement, 1992; Galili, Bendall, & Goldberg, 1993; Scott, 1992). This approach serves two key purposes: first, it provides detailed insights into whether restructuring occurs gradually through weak changes or via more profound strong restructuring; and second, it informs the development of targeted instructional strategies tailored to different phases of the learning progression (Brown & Clement, 1992).

### **The effectiveness of inquiry-based learning**

Numerous studies have consistently demonstrated that inquiry-based learning positively influences students' achievement in science education, particularly when contrasted with traditional laboratory instruction, which often falls short of fulfilling educational objectives (Bybee, 2004; Duschl et al., 2007; Russell et al., 2011). As Anderson (2002) succinctly states, inquiry teaching generally yields beneficial outcomes. Supporting this, Von Secker (2002) highlights substantial empirical and theoretical evidence indicating that inquiry-based instruction serves as a foundational approach for learners to personally construct meaning, thereby promoting higher academic achievement across diverse student populations. Specifically, Von Secker's research identified a significant positive impact on students' conceptual understanding, as measured through science achievement tests following inquiry-based instruction. Additionally, Gerber et al. (2001) reported that inquiry-based teaching methods effectively enhance students' reasoning skills, further underscoring the pedagogical value of this approach.

### **Inquiry-Based Learning and Physics Education:**

Research indicates that Inquiry-Based Learning (IBL) effectively enhances critical thinking skills and deepens conceptual understanding in science education (Hmelo-Silver et al., 2007; Abrahams & Reiss, 2012). For example, Cavallo and Laubach (2001) reported that students engaged in inquiry-driven instructional approaches outperformed their peers in traditional settings on conceptual physics assessments. IBL has been demonstrated to increase student engagement, promote scientific reasoning, and improve comprehension of complex concepts (Hmelo-Silver et al., 2007). Nonetheless, the widespread adoption of IBL faces considerable challenges worldwide, particularly in contexts where educators lack adequate support or confidence to implement these methods effectively (Abrahams & Reiss, 2012). Key obstacles to successful IBL integration include insufficient teacher training, limited instructional time, scarcity of laboratory materials, and resistance to altering established teaching routines (Kang & Keinonen, 2017). Additionally, educators often encounter difficulties in managing the open-ended nature of inquiry activities and in assessing students' conceptual learning progress. These challenges highlight the pressing need for focused research that examines the practical enactment of IBL in authentic classroom environments and evaluates its impact on students' conceptual understanding, especially in the context of senior high school physics education.



## Theoretical Frameworks

### Conceptual Change Model

According to Powell and Kalina (2009), two fundamental principles of Piaget's cognitive theory are assimilation and accommodation, which are used differently than their common everyday meanings and must be understood within the framework of constructivist epistemology. Assimilation refers to the cognitive process whereby learners incorporate new information and experiences into their pre-existing mental frameworks or schemas without changing the original structure. This means that external elements are integrated into the existing cognitive structures, allowing the learner to interpret novel stimuli in terms of what is already known. Assimilation facilitates the learner's ability to maintain continuity in understanding by fitting new data into familiar concepts. In contrast, accommodation involves altering one's cognitive structures to adapt to information or experiences that cannot be incorporated through assimilation alone. This process leads to transformation and expansion of cognitive schemas, enabling deeper intellectual growth and more accurate comprehension of the environment. Together, assimilation and accommodation drive the dynamic intellectual development described by Piaget, as learners progressively refine and reconstruct their knowledge in response to ongoing experiences. This dual mechanism captures the continuous interplay between stability and change in cognitive development central to Piaget's theory of conceptual change.

### Cognitive Constructivism: The Context of Scheme Theory

Powell and Kalina (2009) highlight two fundamental concepts in Piaget's theory of cognition: assimilation and accommodation. These terms differ in meaning from their everyday use and should be understood within Piaget's constructivist framework of knowledge development. Assimilation refers to the process by which elements from the environment are integrated into an individual's existing cognitive structure, while accommodation involves adjusting that cognitive structure to better fit the new information. To illustrate, Piaget describes how an infant learns that shaking a rattle produces a pleasant sound, which forms a cognitive scheme consisting of three parts: recognizing an object with certain features (a graspable item with a rounded end), associating an action with the object (grasping and shaking it), and expecting a specific outcome (the noise). When this infant later encounters a spoon, it assimilates the spoon into the rattling scheme because the spoon shares some observable characteristics, such as a rounded end. To the infant, the spoon effectively functions like a rattle initially. However, shaking the spoon does not produce the anticipated rattling noise, causing a cognitive disruption or "perturbation," which triggers learning and adaptation.

This perturbation may cause the infant to focus attention on the spoon and notice features that differentiate it from a rattle, leading to accommodation through modification of the existing schema—a relatively minor adjustment. Alternatively, if shaking the spoon causes it to hit the table and generate a different but rewarding sound, this new experience also creates a perturbation, potentially prompting a more significant accommodation. This latter scenario might result in forming a novel "spoon banging" schema.

According to Kalina and Powell (2009), Piaget's learning theory can be summarized as a process where cognitive change and learning occur when an existing scheme fails to produce the expected outcome, leading to perturbation. This disequilibrium then motivates accommodation, which restructures the learner's cognitive framework and restores balance. Hence, learning is viewed as an adaptive and instrumental process that evolves through resolving contradictions between prior expectations and new experiences.

### Cognitive Constructivism: Knowledge as an Adaptive Function

Jean Piaget, widely regarded as the most influential constructivist thinker of the twentieth century, dedicated much of his work to developing a model that explains how viable knowledge is generated. Piaget's understanding of "viability" is derived from evolutionary theory, where adaptation describes the state of an organism or species that enables it to survive successfully within its environment. In both evolutionary biology and constructivist epistemology, the concept of equilibrium is central to viability. In evolution, equilibrium refers to a condition in which an organism or species maintains genetic traits that ensure its continued survival in a particular environment. In the cognitive realm, equilibrium denotes a state in which an individual's cognitive structures consistently produce expected outcomes without generating conceptual conflicts or contradictions.

Importantly, equilibrium in both contexts is not a fixed or static state—like a balance beam at rest—but rather a dynamic condition, akin to the continuous adjustments a cyclist makes to remain upright. To fully appreciate Piaget's notion of knowledge, it is essential to recognize another critical dimension frequently overlooked by many scholars: the inherently social nature of human experience. Learning and knowledge construction always

involve interactions with other thinking individuals. This social aspect becomes particularly significant in educational settings, where teachers actively engage in fostering or reshaping the cognitive development of students through guided interaction.

### **Research Gaps and Rationale for the Study**

Despite substantial evidence endorsing the effectiveness of Inquiry-Based Learning (IBL) in science education, there remains a notable scarcity of qualitative investigations examining how IBL influences students' conceptual understanding within authentic high school physics classrooms, particularly in under-resourced settings. The bulk of existing research predominantly employs quantitative methodologies or is concentrated in Western educational contexts, thereby limiting the generalizability and relevance of findings to diverse cultural and infrastructural environments. Additionally, there is a significant gap in the literature regarding in-depth insights into the lived experiences and perspectives of both educators and learners actively involved in inquiry-driven physics instruction. Addressing these gaps is crucial for developing contextually responsive pedagogical strategies that enhance conceptual learning in settings where resource constraints and contextual factors pose unique challenges.

### **Research Design and Methodology**

#### **Research Paradigm:**

The study is grounded in the constructivist-interpretivist research paradigm, which assumes that knowledge and understanding are socially constructed through interactions and shared experiences. This paradigm emphasizes that reality is subjective and best explored by capturing the lived experiences and perspectives of participants within their social contexts. It holds that meaning emerges from the dynamic interplay between researchers and participants, allowing for co-construction of knowledge that reflects the complexity and depth of human behavior. Adopting this approach enables the study to delve deeply into how Inquiry-Based Learning is implemented and experienced in real educational settings, valuing the unique insights of teachers and students to generate authentic, context-rich explanations. Such a paradigm prioritizes empathy, reflexivity, and ethical engagement throughout the research process, aiming not only for understanding but also for socially meaningful contributions (Creswell & Poth, 2018).

#### **Research design**

The study adopts a qualitative case study research design to provide an in-depth exploration of the implementation and impact of Inquiry-Based Learning (IBL) within selected high school physics classrooms. This approach enables an intensive examination of a contemporary phenomenon within its real-life educational context, allowing for a comprehensive understanding of the complexities and interactions involved. By focusing on specific cases—namely, individual schools, teachers, and students—the research captures detailed contextual insights and lived experiences that quantitative methods may overlook. The design is flexible, allowing for iterative data collection and analysis to deepen understanding as study progresses. It emphasizes rich, thick descriptions that bring out the nuances of how IBL is enacted and experienced, thus facilitating nuanced interpretations of the findings. Such a design is well-suited for educational research aiming to uncover multifaceted processes and outcomes, supporting rigor, authenticity, and meaningful contributions suitable for publication in reputable academic outlets.

#### **Setting and Participants**

A qualitative case study design will be employed to investigate the implementation and effects of Inquiry-Based Learning (IBL) in senior high school physics classrooms. The study will purposively select 4 high schools known for their active use of IBL. From these schools, 6 physics teachers will be involved to provide a range of instructional insights, while approximately 40 students will be purposively sampled to capture diverse perspectives and experiences.

#### **Data Collection**

Data for this study were collected using semi-structured interviews and focus group discussions guided by an interview protocol (see Appendix). The protocol consisted of open-ended questions designed to explore participants' experiences, perceptions, challenges, and suggestions regarding inquiry-based learning in senior high school physics. These questions were developed to align with the study's objectives of understanding conceptual understanding and instructional practices.

All interviews and discussions were audio-recorded with participant consent and transcribed verbatim for analysis. The use of a consistent question guide ensured systematic data collection across all participants, while

allowing flexibility to probe emerging themes. The full list of questions used to guide the data collection is included in the Appendix to provide transparency and enable replication.

### **Trustworthiness of the Study**

Ensuring the trustworthiness of this qualitative study is fundamental to its rigor and integrity, affirming that the findings authentically represent the participants' experiences. Drawing on Lincoln and Guba's (1985) framework, trustworthiness is established through four interrelated criteria: credibility, transferability, dependability, and confirmability, which correspond to the established quantitative concepts of internal validity, generalizability, reliability, and objectivity, respectively.

*Credibility* is achieved by methods that enhance the accuracy and truthful representation of participants' perspectives. This study employs member checking, allowing participants to review and validate the interpreted data. Prolonged engagement in the research setting enables the researcher to build rapport and gain nuanced understanding of the context. Triangulation of data sources and collection methods strengthens confidence in the consistency of findings.

*Transferability* is addressed by providing detailed, 'thick' descriptions of the research context, participant demographics, and methodological procedures. This enables readers to discern the extent to which the findings may be applicable to other settings, thereby facilitating informed judgments about the relevance of the results beyond the immediate study population.

*Dependability* is maintained through a comprehensive audit trail documenting all decisions made throughout the research process, ensuring transparency and allowing for replication or external scrutiny. This systematic record supports consistency and reliability in data analysis and reporting.

Finally, *confirmability* is ensured by reflexive practices whereby the researcher critically reflects on potential biases and maintains an objective stance, grounding conclusions firmly in the data. The emphasis on reflexivity and contextual sensitivity distinguishes qualitative inquiry from quantitative approaches, focusing on richness and depth rather than standardization.

Together, these elements ensure that this study upholds rigorous qualitative standards, providing trustworthy and meaningful insights into Inquiry-Based Learning in physics education within under-resourced contexts.

### **Ethical Considerations**

This study will adhere strictly to established ethical standards to protect the rights, dignity, and welfare of all participants. Prior to data collection, informed consent will be obtained from all participating teachers and students, ensuring they fully understand the study's purpose, procedures, potential risks, and their voluntary right to withdraw at any time without penalty.

Confidentiality and anonymity will be maintained by assigning pseudonyms and removing identifying information from transcripts and reports to protect participants' privacy. All data will be stored securely, accessible only to the research team, and will be destroyed in accordance with institutional guidelines after the study's completion.

Special attention will be given to safeguarding vulnerable participants, particularly students, by ensuring that their participation does not interfere with their academic responsibilities or cause distress. The study will also seek ethical approval from relevant institutional review boards or ethics committees before commencement, complying with all local and international research ethics regulations.

By fostering an ethical research environment founded on respect, transparency, and responsibility, this study aims to contribute valuable insights while prioritizing participants' well-being and rights.

### **Data Analysis and Thematic Presentation**

The qualitative data from the focus group discussions were analyzed using Braun and Clarke's (2006) six-phase thematic analysis method, which involves a systematic process to identify, examine, and report significant patterns and themes within the participants' accounts. This approach begins with deep immersion in the data, followed by generating initial codes, and then grouping these codes into meaningful themes. These themes are then reviewed and refined to ensure they accurately capture the data's nuances. After defining and naming each theme clearly, the final phase involves compiling an interpretive narrative that links these themes to the research question and broader literature. The resultant themes encapsulate the key experiences and viewpoints of both teachers and students concerning Inquiry-Based Learning (IBL) in senior high school physics classes, supported

by illustrative quotations to enhance understanding and credibility. This process allows for an insightful and structured presentation of the findings grounded in participants' lived experiences.

## RESULTS AND DISCUSSION

Table 1: Key themes and illustrative quotes on inquiry-based learning (IBL) implementation and impact

Theme	Illustrative Quotation
Implementation of IBL Strategies	"I encourage students to ask questions and explore, but limited materials and large classes hinder full hands-on inquiry."-Teacher
Students' Experiences with IBL	"Doing experiments and exploring ideas myself makes learning more interesting and helps me understand concepts better than just listening to explanations"-Student
Impact on Conceptual Understanding	"I used to memorize formulas, but now I understand and can explain why phenomena like falling objects occur."- Student
Challenges and Supports in Implementation	"Managing time and syllabus coverage is challenging, but colleague support and simple experiments help ease the process"-Teacher

### Key Findings and Discussion

#### Implementation of IBL Strategies

Teachers recognized their efforts to promote student inquiry by encouraging question-asking and investigation. However, ongoing challenges such as inadequate teaching resources and large class sizes significantly limit the full enactment of hands-on, exploratory Inquiry-Based Learning (IBL). These barriers are consistent with previous studies pointing to resource scarcity as a common obstacle to effective IBL in developing countries (Buabeng et al., 2020; Kang & Keinonen, 2017). The findings indicate that although teachers support student-centered inquiry, practical classroom constraints often require compromises that reduce the depth and quality of inquiry experiences.

#### Students' Experiences with IBL

Students reported that actively engaging in experiments and exploring ideas themselves significantly boosted their interest and understanding, contrasting with the more passive experience of listening to lectures. This feedback aligns with well-established research showing that Inquiry-Based Learning (IBL) enhances student motivation, engagement, and deeper conceptual grasp (Hmelo-Silver et al., 2007; Cavallo & Laubach, 2001). The findings support the constructivist principle that learning is most effective when students interact directly with content, enabling them to build meaningful, personalized knowledge rather than passively receiving information.

#### Impact on Conceptual Understanding

Students reported a progression from rote memorization of formulas to the ability to comprehend and articulate the fundamental physical principles behind phenomena. This outcome highlights the success of Inquiry-Based Learning (IBL) in facilitating conceptual change, corroborating earlier research that shows inquiry methods enhance students' understanding of physics concepts (Von Secker, 2002; Gerber et al., 2001). Moving beyond procedural knowledge to develop meaningful understanding is essential for addressing common misconceptions in physics education (Bao & Redish, 2006). Inquiry-based approaches promote knowledge restructuring, enabling learners to internalize concepts deeply rather than superficially memorizing facts.

#### Challenges and Supports in Implementation

Time constraints and the pressure to cover the curriculum emerged as significant challenges, with teachers finding it difficult to integrate inquiry activities within limited instructional time. However, supportive collaboration with colleagues and creative use of simple experimental resources eased some of these pressures. This aligns with research by Choudhary (2016) and Kibirige et al. (2014), who highlight the importance of ongoing professional development and peer support as key factors in sustaining effective inquiry-based teaching. The findings

emphasize that institutional backing and adaptable teaching approaches are crucial for the successful adoption of Inquiry-Based Learning.

### Discussion

The findings of this study align with a broad base of international research showing that Inquiry-Based Learning (IBL) significantly improves both students' conceptual understanding and engagement in physics (Hmelo-Silver et al., 2007; Von Secker, 2002). However, widespread obstacles such as lack of resources, large class sizes, and entrenched traditional teaching practices commonly found in many developing countries hinder the full realization of IBL's potential (Buabeng et al., 2020; Kang & Keinonen, 2017). These challenges mirror systemic issues highlighted in curriculum reform literature, which emphasize that successful pedagogical innovation requires not only instructional resources but also ongoing professional support (Abrahams & Reiss, 2012).

Notably, the students' positive reactions reflect constructivist learning theories emphasizing active inquiry and social interaction as essential for learning (Piaget, 1972; Vygotsky, 1978). The shift observed from memorizing facts to developing explanatory understanding supports models of conceptual change, underscoring that genuine science learning involves reconfiguring prior knowledge through hands-on and reflective experiences (Chi, 2009; Posner et al., 1982).

Moreover, the results highlight the critical role of continuous teacher development and collaborative support frameworks to overcome practical hurdles to IBL implementation. The formation of professional learning communities and provision of context-sensitive teaching materials empower educators to innovate despite challenges (Kibirige et al., 2014; Choudhary, 2016). Ultimately, designing effective inquiry-based instruction depends on systemic commitment to align curriculum requirements with the realistic conditions of classrooms.

### Implications for Practice

This study highlights the urgent need for focused professional development that equips teachers with effective Inquiry-Based Learning (IBL) strategies, particularly for resource-challenged environments. Such training should extend beyond theoretical pedagogy to include practical adaptations for challenges like crowded classrooms and limited lab materials. Additionally, establishing collaborative professional learning communities will offer ongoing peer support, opportunities to exchange best practices, and collective problem-solving.

Educational institutions and policymakers must prioritize resource allocation to support hands-on inquiry experiences, even though affordable or improvised materials, ensuring students engage in meaningful experiential learning critical for developing conceptual understanding. Curricula should be designed to provide ample time for inquiry-based processes, balancing comprehensive syllabus coverage with deep, thoughtful learning to avoid superficial treatment of topics.

Emphasizing learner-centered teaching approaches that encourage active exploration and critical thinking can revolutionize physics education, transitioning students from rote memorization to genuine understanding. Engaging learners in inquiry fosters conceptual change and nurtures scientific reasoning skills necessary for lifelong learning and effective problem-solving.

### Conclusion

This study highlights the powerful impact of Inquiry-Based Learning (IBL) on improving students' conceptual understanding and engagement in senior high school physics. Despite students experiencing greater comprehension and interest through active inquiry, teachers are often hindered by infrastructural and systemic challenges. Overcoming these obstacles is crucial to unlocking IBL's full benefits. The results emphasize that effective inquiry-based science education relies heavily on strong teacher support, adequate resourcing, and curriculum adaptations tailored to specific contexts, especially in resource-constrained settings. Ultimately, cultivating a learning environment that prioritizes inquiry and deep understanding over memorization prepares students more effectively for advanced scientific studies and practical applications.

### Recommendations

- Educational authorities, such as Ministries of Education, should provide continuous professional development programs focused on inquiry-based teaching methods adapted to local classroom challenges.
- School management should ensure the availability of affordable, accessible materials and laboratory equipment to support hands-on inquiry in physics teaching.
- Curriculum planners need to design flexible frameworks that allocate sufficient time for inquiry-based learning while ensuring comprehensive syllabus coverage.
- Educational institutions and teacher professional bodies ought to establish collaborative networks for teachers to share inquiry strategies and resources and provide mutual support.

- Research organizations should promote qualitative and action research to monitor and address ongoing challenges in inquiry implementation across diverse educational environments.
- Policymakers should advocate for prioritizing inquiry-based science education with aligned funding and policies to sustain and scale teacher training, resource provision, and curricular innovation.

### Acknowledgements

The authors wish to express their sincere gratitude to Prof. Peter Akayuru for his invaluable guidance and support throughout the course of this study. We appreciate his insightful suggestions and encouragement, which greatly contributed to the successful completion of this research assignment.

### References

- Abrahams, I., & Reiss, M. (2012). *Practical work in secondary science: A minds-on approach*. Continuum.
- Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, 13(1), 1–12. <https://doi.org/10.1023/A:1015171124982>
- Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. Holt, Rinehart & Winston.
- Bao, L., & Redish, E. F. (2006). Model analysis: Representing and assessing the dynamics of student learning. *Physical Review Special Topics – Physics Education Research*, 2(1).
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
- Breen, K. C., Dotson, M. E., Madonna, M. C., Asturias, G., Pena, D. M., Springate, H., & Ramanujam, N. (2023). Community-Centered Design Thinking as a Scalable STEM Learning Intervention. *Advances in Engineering Education*, 11(2), 2–33.
- Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, 31(1), 21–32.
- Buabeng, I., Ntow, F. D., & Ampiah, J. G. (2020). Ghanaian science teachers' conceptions of inquiry-based instruction. *International Journal of Science Education*, 42(5), 745–764.
- Bybee, R. W. (2004). The National Science Education Standards: Where we are and where we need to go. *The Phi Delta Kappan*, 86(7), 510–517.
- Bybee, R. W., Powell, J. C., & Trowbridge, L. W. (2008). *Teaching secondary science: Strategies for developing scientific literacy*. Pearson.
- Carey, S. (1986). Cognitive science and science education. *American Psychologist*, 41(10), 1123–1130.
- Cavallo, A. M. L., & Laubach, T. A. (2001). Students' science perceptions and enrollment decisions in differing learning cycle classrooms. *Journal of Research in Science Teaching*, 38(9), 1029–1042.
- Champagne, A. B., Klopfer, L. E., & Gunstone, R. F. (1982). Cognitive research and the design of science instruction. *Educational Psychologist*, 17(1), 31–53.
- Chi, M. T. (2009). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In *International handbook of research on conceptual change* (pp. 89–110). Routledge.
- Chiaverina, C., & Vollmer, M. (2005). Learning physics from the experiments. In *Informal Learning and Public Understanding of Physics* (pp. 185–190). Retrieved from <http://www.girep2005.fmf.uni-lj.si/dwreport/dwb.pdf>
- Choudhary, F. R. (2016). Effect of inquiry-based instruction on student's attitude and academic achievement in Physics. *Science International (Lahore)*, 28(4), 91–94.

- Clement, J., Brown, D., & Zietsman, A. (1989). Not all preconceptions are misconceptions: Finding 'anchoring conceptions' for grounding instruction on students' intuitions. *International Journal of Science Education*, 11(5), 554–565.
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Sage Publications.
- Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.). (2007). *Taking science to school: Learning and teaching science in grades K-8*. National Academies Press.
- Fosnot, C. T. (2013). *Constructivism: Theory, Perspectives, and Practice* (2nd ed.). Teachers College Press.
- Galili, I., Bendall, S., & Goldberg, F. (1993). The effects of prior knowledge and instruction on understanding image formation. *Journal of Research in Science Teaching*, 30(3), 271–301.
- Gerber, B. L., Cavallo, A. M. L., & Marek, E. A. (2001). Relationships among informal learning environments, teaching procedures, and scientific reasoning ability. *International Journal of Science Education*, 23(5), 535–549.
- Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning*, 3(2), 16.
- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning. *Educational Psychologist*, 42(2), 99–107. <https://doi.org/10.1080/00461520701263368>
- Kang, J., & Keinonen, T. (2017). The effect of inquiry-based learning experiences on adolescents' science-related attitudes and career aspirations. *International Journal of Science Education*, 39(5), 554–573.
- Kibirige, I., Osodo, J., & Mgiba, D. (2014). The effectiveness of inquiry-based teaching on students' conceptual understanding of science. *Mediterranean Journal of Social Sciences*, 5(4), 300–308.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage Publications.
- Piaget, J. (1972). *The psychology of the child*. Basic Books.
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211–227.
- Powell, K. C., & Kalina, C. J. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. *Education*, 130(2), 241–250.
- Redish, E. F. (1994). Implications of cognitive studies for teaching physics. *American Journal of Physics*, 62(9), 796–803.
- Rumelhart, D. E., & Norman, D. A. (1978). *Accretion, tuning and restructuring: Three modes of learning*. University of California.
- Russell, S. H., Hancock, M. P., & McCullough, J. (2011). Benefits of undergraduate research experiences. *Science*, 316(5824), 548–549.
- Scott, P. (1992). Pathways in learning science: A case study of the development of one student's ideas. In *Research in physics learning: Theoretical issues and empirical studies* (pp. 203–224).
- Shymansky, J. A., & Kyle, W. C. (2008). Learning and the learner. *Science Education*, 72(3), 293–304.
- Spronken-Smith, R. (2012). Experiencing the process of knowledge creation: The nature and use of inquiry-based learning in higher education. *International Colloquium on Practices for Academic Inquiry*, University of Otago.

Von Secker, C. E. (2002). Effects of inquiry-based teacher practices on science excellence and equity. *The Journal of Educational Research*, 95(3), 151–160. <https://doi.org/10.1080/00220670209596585>

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Yuliati, L., Hapsari, A. A., Nurhidayah, F., & Halim, L. (2018). Building scientific literacy and concept achievement through inquiry-based learning for STEM education. *Journal of Physics: Conference Series*, 1108, 012026. IOP Publishing.

#### **Appendix: Interview/Focus Group Questions**

1. Can you describe your experience with inquiry-based learning in your physics classes?
2. How do you think inquiry-based learning has affected your understanding of physics concepts?
3. What challenges have you encountered when engaging in inquiry-based learning?
4. How do teachers support or guide inquiry-based learning in your classroom?
5. Can you share a specific example of a physics topic that was easier or harder to understand through inquiry-based learning?
6. What role does collaboration with classmates play during inquiry-based learning activities?
7. How do you feel inquiry-based learning compares with traditional methods like lectures or note-taking?
8. What resources or materials do you find most helpful during inquiry-based learning sessions?
9. How confident do you feel applying what you learned through inquiry-based learning to solve physics problems?
10. What suggestions do you have for improving inquiry-based learning in physics education?

