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BACHELOR OF SCIENCE HONOURS DEGREE IN PHYSICS

**TITLE: THE EFFECT OF INQUIRY-BASED LEARNING ON STUDENT'S
CONCEPTUAL UNDERSTANDING OF NEWTONIAN MECHANICS IN
SECONDARY SCHOOLS**

BY MUHOMBA PHOEBE

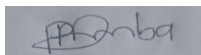
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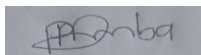
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The undersigned certify that they have read and recommended to the Bindura University of Science Education for the acceptance of a research titled: the effect of inquiry-based learning on student's conceptual understanding of Newtonian mechanics in secondary schools

Done by Muhomba Phoebe in partial fulfilment of the Bachelor of Science Education Honours Degree in Physics



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RELEASE FORM

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PROJECT TITLE: The Effect of Inquiry-Based Learning on Students' Conceptual Understanding of Newtonian Mechanics in Secondary Schools.

Program Bachelor of Science Education Honours Degree in Physics Year Granted
2025

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DEDICATION

This project is dedicated to my children: Valentine and Ryan, and my grandchildren: Adler and Adeline. Your love, encouragement and understanding have been my greatest source of strength and inspiration throughout this journey.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my supervisor, Dr. Ndemo, for his invaluable guidance, encouragement, and constructive feedback throughout this research. His mentorship and support made this study possible. My sincere appreciation also goes to my Headmaster, Mr. Maringehosi, for granting me permission and support to conduct this study at the school. Special thanks go to Mr. Chikerema, whose assistance, motivation, and words of encouragement were instrumental during the research process. Finally, I extend my heartfelt appreciation to all the teachers and learners who participated in the study. Their cooperation and honest responses contributed greatly to the success of this research.

ABSTRACT

Physics education, particularly in the domain of Newtonian mechanics, continues to pose significant challenges for secondary school learners due to its abstract nature, reliance on mathematics, and the persistence of deeply ingrained misconceptions. Traditional teacher-centered, lecture-based instruction has proven inadequate in fostering the conceptual change necessary for genuine scientific literacy, often resulting in poor performance and student disengagement. This study investigated the effectiveness of Inquiry-Based Learning (IBL) in enhancing students' conceptual understanding of Newtonian mechanics within Zimbabwean secondary schools. Specifically, it compared the academic performance and attitudes of students taught using IBL strategies with those taught through traditional lecture methods, while also exploring the challenges teachers encountered in implementing IBL in resource-constrained environments.

A mixed-methods approach was employed, utilizing diagnostic tools such as the Force Concept Inventory (FCI), structured questionnaires, and semi-structured interviews to capture both quantitative and qualitative data. Findings demonstrated that IBL significantly improved conceptual mastery and remediated prevalent misconceptions more effectively than traditional methods. Furthermore, the results indicated that IBL fostered positive attitudes towards physics by promoting critical thinking, collaboration, and active engagement. Despite these benefits, the study identified significant implementation hurdles, including limited laboratory apparatus and time constraints within the syllabus. This research contributes to the limited body of context-specific research on IBL in sub-Saharan Africa, offering practical insights for teachers, policymakers, and curriculum developers. Ultimately, the study highlights the potential of IBL as a transformative instructional model capable of bridging the gap between abstract scientific principles and meaningful student learning in Zimbabwean classrooms.

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1.1 Introduction

In an era defined by rapid technological advancement and global competition, the cultivation of robust Science, Technology, Engineering, and Mathematics (STEM) capabilities has become a strategic imperative for national development. Physics, as the foundational science that underpins engineering and technology, serves as a critical gateway discipline. A strong conceptual understanding of physics is not merely an academic requirement; it is a catalyst for innovation, equipping citizens with the critical thinking skills necessary to solve complex problems and participate meaningfully in a knowledge-based economy.

However, for a vast number of secondary school students, the gateway to physics has historically remained shut. The subject is widely perceived as abstract, mathematically intensive, and conceptually challenging, leading to widespread disengagement and a decline in enrolment in advanced science courses (Munikwa, 2022). This challenge was most acute in the study of Newtonian mechanics, a cornerstone of the physics curriculum. The principles of mechanics often defy students' everyday intuitions, creating a fertile ground for misconceptions that proved remarkably resistant to conventional instruction.

The persistence of these learning difficulties suggested a crisis in science pedagogy, indicating that dominant teaching models were ill-equipped to foster deep conceptual understanding. For decades, the Zimbabwean educational landscape was dominated by teacher-centered, lecture-based instruction (Chikodzi & Nyota, 2022). This "chalk-and-talk" approach prioritized the transmission of information over conceptual depth. In response, this study investigated a paradigm shift toward Inquiry-Based Learning (IBL). While the theoretical benefits of IBL were well-articulated internationally, its practical application within the unique socio-economic realities of Zimbabwean secondary schools remained an area ripe for empirical investigation. Therefore, this study bridged this gap by rigorously investigating the efficacy of IBL as an instructional strategy for enhancing the conceptual understanding of Newtonian mechanics among secondary school students in Zimbabwe.

1.2 Background of the Study

1.2.1 The Challenge of Learning Physics

The reputation of physics as a difficult subject stems from its abstract nature, requiring students to build mental models of phenomena that cannot be directly observed. Furthermore, the inextricable link to mathematics creates a non-trivial hurdle for many learners. Consequently, the subject has frequently been ranked among the most challenging, a perception that contributed to a cycle of anxiety and poor performance (Munikwa, 2022).

1.2.2 Conceptual Hurdles in Newtonian Mechanics

Newtonian mechanics is saturated with concepts that clash with everyday experiences. Students often arrived with "impetus theory"—the intuitive belief that a continuous force is required to keep an object in motion. Diagnostic tools like the Force Concept Inventory (FCI) consistently revealed that these misconceptions were widespread and often persisted even after a full course of traditional instruction, indicating they were robust mental frameworks that required active dismantling (Muringani, 2023).

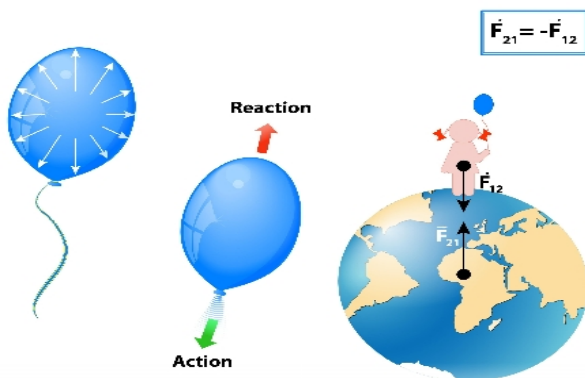


Figure 1: Newton's third law

1.2.3 Shortcomings of Traditional Teaching Methods

The traditional pedagogical model, which still prevailed in many Zimbabwean classrooms, was ill-suited to the task of conceptual change. By treating students as passive recipients, the method failed to engage prior conceptions or provide experiences that challenged misconceptions. As a result, learning remained superficial (Chikodzi & Nyota, 2022).

1.2.4 Inquiry-Based Learning (IBL) as a Solution

IBL offered a fundamentally different approach rooted in constructivist theory. In this study's IBL environment, the teacher's role transformed from a "sage on the stage" to a "guide on the side." By initiating learning through puzzling phenomena, students were empowered to drive their own learning. This process forced students to confront the limitations of their intuitive ideas and build more scientifically accurate mental models (Muringani, 2023).

1.2.5 The Research Gap in the Zimbabwean Context

Despite international support for IBL, there was a significant paucity of context-specific research within Zimbabwean secondary schools. The environment presented unique challenges, including the exam-oriented nature of the ZIMSEC syllabus and severe resource constraints such as large class sizes and shortages of laboratory equipment (Munikwa, 2022; Muringani, 2023).

1.3 Statement of the Problem

Despite the central role of Newtonian mechanics, a significant number of Zimbabwean students failed to achieve a functional conceptual understanding of its principles. The dominant teacher-centered approach proved inadequate for addressing deep-seated conceptual challenges. While IBL was recognized internationally as a potent strategy, its specific effectiveness within the resource-constrained environment of Zimbabwean secondary schools remained a critical, unanswered question (Chikodzi & Nyota, 2022; Muringani, 2023). This study, therefore, confronted the problem of entrenched poor conceptual understanding by investigating the potential of IBL as a superior instructional model and identifying the practical barriers to its implementation.

1.4 Research Objectives

The study aimed to achieve the following objectives:

1. To investigate the effectiveness of Inquiry-Based Learning in improving students' conceptual understanding of Newtonian mechanics.
2. To compare the academic performance of students taught using IBL with those taught using traditional lecture methods.
3. To examine students' attitudes towards learning physics when exposed to IBL strategies.

4. To explore the challenges faced by teachers in implementing Inquiry-Based Learning in physics classrooms.

1.5 Research Questions

The study was guided by the following research questions:

1. To what extent did Inquiry-Based Learning improve students' understanding of Newtonian mechanics compared to traditional teaching methods?
2. What specific misconceptions did students hold about key concepts in Newtonian mechanics before and after exposure to IBL, compared to those in the control group?
3. How did Inquiry-Based Learning influence students' attitudes towards learning physics?
4. What challenges did teachers encounter when implementing IBL in teaching physics in a typical secondary school setting?

1.6 Significance of the Study

The findings of this research were significant for various stakeholders:

- For Students: The study identified effective strategies to improve mastery, potentially leading to better performance and career interest.
- For Teachers: It provided evidence-based insights into alternative pedagogies and concrete strategies for the classroom.
- For Policymakers: The findings informed decisions regarding curriculum reforms and the allocation of resources for science education.
- For Researchers: This study contributed to the body of knowledge regarding IBL in developing country contexts, filling a critical literature gap.

1.7 Definition of Key Terms

- **Inquiry-Based Learning (IBL):** A student-centered approach where learning was driven by a process of inquiry, with the teacher acting as a facilitator.
- **Conceptual Understanding:** A functional grasp of scientific principles involving the ability to apply knowledge to solve novel problems.

- Newtonian Mechanics: The branch of physics concerned with the motion of macroscopic objects under forces, based on Newton's laws.
- Misconceptions: Ideas inconsistent with scientific understanding, often deeply held and resistant to change.
- Traditional Lecture Method: A teacher-centered model where students were largely passive recipients of information.
- Constructivism: A theory emphasizing the active role of the learner in building understanding from experience.

1.8 Structure of the Dissertation

This dissertation was organized into five chapters.

Chapter 1 provided the introduction and background.

Chapter 2 presented a review of relevant literature and theoretical frameworks.

Chapter 3 detailed the research methodology and step-by-step process of data collection.

Chapter 4 presented the analysis and interpretation of the collected data.

Chapter 5 provided a summary, discussed findings in relation to existing literature, and offered practical recommendations.

1.9 Limitations of the Study

The study was subject to several factors beyond the researcher's control:

- Resource Constraints: Shortages of laboratory equipment in some schools limited the full execution of certain IBL activities.
- Teacher Preparedness: The effectiveness of IBL was influenced by the varying degrees of familiarity teachers had with facilitative instruction.
- Time Constraints: The study was conducted over a limited duration, which may have affected the observation of long-term conceptual shifts.

1.10 Delimitations of the Study

The scope of the study was intentionally bounded by the following:

- **Focus on Newtonian Mechanics:** The research was confined to mechanics, excluding other topics like electricity or waves.
- **Secondary School Level:** The study targeted students preparing for ZIMSEC examinations.
- **Comparison of Two Pedagogies:** The study specifically compared IBL with the traditional lecture method.
- **Geographical Context:** The research was conducted within selected Zimbabwean secondary schools.

1.11 Scope of the Project

The project evaluated the effectiveness of IBL in enhancing conceptual understanding of force, motion, and Newton's laws. It involved students, teachers, and administrators across a range of socio-economic conditions. Data were collected over a defined instructional unit using the Force Concept Inventory (FCI), questionnaires, and interviews to assess the immediate impact of the pedagogical intervention on understanding and attitudes.

1.12 Chapter Summary

In summary, this chapter laid the foundational groundwork for the entire study. It began by establishing the critical importance of physics as a gateway STEM discipline and highlighted the widespread challenge of poor conceptual understanding, particularly within the domain of Newtonian mechanics. The chapter identified the dominance of traditional, teacher-centered instruction as a key factor contributing to this problem, noting its failure to effectively address students' deeply ingrained misconceptions. In response, Inquiry-Based Learning (IBL) was introduced as the student-centered pedagogical alternative investigated in this research.

The chapter narrowed its focus to the specific context of Zimbabwean secondary schools, identifying a significant research gap regarding the practical implementation and effectiveness of IBL within this unique, resource-constrained, and exam-oriented environment. This provided the basis for the Statement of the Problem, which framed the investigation into the efficacy of IBL for improving conceptual understanding of mechanics.

To guide the investigation, the chapter outlined the specific Research Objectives and Research Questions that directed the data collection. The Significance of the Study was articulated for various stakeholders, including students, teachers, policymakers, and researchers. Finally, key

terms were defined, and the study's scope, limitations, and delimitations were explicitly stated to ensure a focused and transparent research process.

Having established the purpose, context, and framework for the study, the next chapter presents a comprehensive review of the relevant literature. Chapter 2 delves into the theoretical underpinnings of conceptual change, explores various models of inquiry-based learning, and synthesizes findings from previous empirical studies on the effectiveness of IBL in physics education globally and within similar contexts.

CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter explores the theoretical foundations of Inquiry-Based Learning (IBL) as a constructivist approach for fostering deep conceptual understanding in science. It examines key instructional frameworks, such as the 5E model and the spectrum of inquiry, which structure students' active construction of knowledge by progressively increasing their autonomy and cognitive engagement. The chapter then defines conceptual understanding as a flexible, transferable grasp of principles achieved through the process of conceptual change, where students replace deeply held misconceptions with scientifically accurate frameworks. To ground these theories in a practical context, the discussion culminates in an analysis of Newtonian Mechanics, a domain notorious for persistent Aristotelian misconceptions, positioning IBL as an essential pathway for dismantling these intuitive errors and cultivating durable scientific literacy.

2.2 Theoretical Frameworks and Empirical Context: Inquiry-Based Learning and Conceptual Understanding in Physics

Inquiry-Based Learning is a pedagogical approach founded upon modern learning theories that assert knowledge acquisition is an active, constructive process (Piaget, 1970; Vygotsky, 1978; Moemeke et al., 2025). Within this constructivist paradigm, learning occurs through the systematic construction of science-based knowledge structures. The purpose of knowledge transfer in IBL is directed toward the process of inquiry itself, combining conscious and unconscious perception. This approach necessitates that the circumstances in which knowledge is acquired and subsequently used must be clearly established at the outset of the academic period, providing a necessary context for the learning (Moemeke et al., 2025).

IBL represents a fundamental shift away from passive knowledge reception. It emphasizes presenting students with authentic and often ill-structured problems around contemporary scientific issues, which serve to challenge students cognitively and enhance their ability to problem-solve (Moemeke et al., 2025). By actively engaging in finding solutions, students are able to construct knowledge in a reliable and stable way, fulfilling a key principle of the constructivist framework.

2.2.1 Key Instructional Models for IBL in Secondary Science

To manage the complexity of investigative learning, pedagogical models provide a structural framework for implementation. One prominent structure utilized in secondary science education is the 5E instructional model (Bybee, 1997). This model functions as a planning tool for inquiry teaching, sequencing coherent learning experiences that help students connect formal scientific ideas with their pre-existing experiences (Moemeke et al., 2025). The 5E model is not merely a procedural checklist but is deeply rooted in the constructivist learning theory, which posits that learners actively construct knowledge by integrating new information with their existing cognitive frameworks. Its lineage can be traced back to the "learning cycle" model developed by Robert Karplus in the 1960s, which itself was influenced by Piaget's stages of intellectual development. This theoretical foundation positions the 5E model as an ideal mechanism for promoting conceptual change, a process essential for overcoming deeply held misconceptions in science.

The initial 'Engage' phase is critical in the context of conceptual change, as it aims to trigger students' curiosity and surface existing understanding (or misunderstanding). This is often achieved by presenting a discrepant event, a puzzling phenomenon, or a compelling question that creates cognitive conflict. This conflict motivates students to reconcile the discrepancy, thereby preparing them for the learning that follows (Abdulrahman, 2022). Subsequent phases ('Explore,' 'Explain') provide the necessary structure for students to practice reasoning skills, develop evidence-based explanations, and communicate their ideas, ensuring that students are cognitively challenged while acquiring content (Moemeke et al., 2025). During the 'Explore' phase, students work collaboratively, often with hands-on materials, to investigate the phenomenon. The teacher acts as a facilitator, guiding inquiry with probing questions rather than providing direct answers. This is followed by the 'Explain' phase, where students are first invited to articulate their own explanations before the teacher introduces formal scientific vocabulary and concepts, thus linking their exploratory experiences to established scientific knowledge.

The final two phases, 'Elaborate' and 'Evaluate,' are crucial for solidifying and assessing learning. In the 'Elaborate' phase, students apply their newly constructed understanding to new situations, which deepens their conceptual grasp and enhances their ability to transfer knowledge. This might involve solving a related problem or designing a new experiment. This phase reinforces the idea that scientific knowledge is not static but a tool for application and further discovery (Liu & Chavez, 2023). The 'Evaluate' phase is both formative and summative,

allowing the teacher to assess student progress throughout the cycle and students to reflect on their own learning. Evaluation goes beyond traditional tests to include performance tasks, presentations, and detailed explanations, providing a more holistic view of student understanding and their ability to engage in scientific practices.

Despite its widespread adoption and support, the 5E model is not without its challenges. Critics point out that its implementation can be time-consuming and requires significant pedagogical content knowledge from teachers to facilitate effectively (Abdulrahman, 2022). There is also a risk of the model becoming a rigid, formulaic exercise if each phase is not executed with depth and responsiveness to student needs. However, empirical evidence continues to support its efficacy. A meta-analysis by Liu and Chavez (2023) found that instruction based on the 5E model produced significantly better outcomes in students' conceptual understanding, scientific reasoning skills, and attitudes toward science compared to traditional, teacher-centered approaches. This systematic approach is therefore essential for guiding the learning process, particularly when addressing counter-intuitive concepts such as those found in Newtonian physics, as it systematically moves students from curiosity to conceptual mastery.

2.2.2 The Spectrum of Inquiry: Autonomy and Cognitive Demand

IBL is not monolithic; its implementation exists across a continuous spectrum defined by the degree of control or autonomy granted to the student versus the guidance provided by the instructor. This spectrum ranges from highly structured activities to fully student-driven investigations, and the level chosen directly correlates with the cognitive demands placed on the learner (Banchi & Bell, 2008; Moemeke et al., 2025). Banchi and Bell (2008) provide a widely cited framework that delineates this spectrum into four distinct levels: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry. In confirmation inquiry, students are given a question and a procedure, and their task is to confirm a known principle, requiring the least cognitive effort. In structured inquiry, the question and procedure are still provided by the teacher, but students must generate their own explanation from the data. The critical shift toward higher-order thinking begins with guided inquiry, where students must devise their own procedure to answer a teacher-provided question, and culminates in open inquiry, where students formulate their own questions, design investigations, and draw conclusions. This progression represents a deliberate transfer of cognitive responsibility from the teacher to the student, fundamentally changing the learner's role from a passive recipient of information to an active participant in the construction of knowledge.

The critical shift along this spectrum occurs when the responsibility for formulating explanations and connecting them to scientific knowledge is transferred from the instructor to the learner. In introductory or highly structured inquiry, the learner is guided or even provided with possible ways to use evidence; however, in guided and open inquiry, the learner must independently examine resources and form the links to their explanations. This increasing self-direction is fundamentally linked to the potential for deep cognitive engagement. As autonomy increases, the necessity for the learner to engage in the active dismantling and restructuring of their prior knowledge framework—a key requirement for robust conceptual change—grows significantly. This process aligns with Posner et al.'s (1982) model of conceptual change, which posits that for students to abandon a pre-existing conception, they must first become dissatisfied with it and then find a new conception to be intelligible, plausible, and fruitful. Guided and open inquiry are uniquely suited to create these conditions. However, this transition is not without its challenges, as scaffolded autonomy can lead to cognitive overload for novice learners (Hmelo-Silver et al., 2007). Therefore, the efficacy of IBL in achieving lasting conceptual understanding is deeply mediated by the instructional level chosen and the quality of teacher-provided scaffolding that supports students as they navigate the demands of increased independence (Moemeke et al., 2025).

2.2.3 Defining Conceptual Understanding (CU)

Conceptual Understanding is a pedagogical outcome defined as grasping the underlying "why" behind ideas, moving fundamentally beyond the mechanical memorization of isolated facts or procedures (Moemeke et al., 2025). This practical understanding allows students to see beyond single facts and approaches, recognizing the relationship between different pieces of information. When knowledge is constructed in this reliable and stable way, it creates stronger, more accessible neural pathways than rote learning, leading to higher information retention (Moemeke et al., 2025). The most significant hallmark of true comprehension achieved through CU is flexibility: students who grasp concepts can apply their knowledge in varied contexts, adapting what they have learned in one situation to solve problems in entirely different scenarios (Moemeke et al., 2025). Furthermore, students with strong CU can identify overarching principles and patterns, moving beyond specific examples to understand broader themes that apply across multiple situations. Because content details frequently change, while fundamental concepts remain stable, conceptual learning is viewed as highly durable and adaptable for continuous improvement (Moemeke et al., 2025).

Assessing this depth of understanding, therefore, requires a paradigm shift away from conventional, recall-based evaluation methods. Traditional multiple-choice or short-answer tests often fail to capture a student's ability to apply knowledge or articulate their reasoning, instead measuring only fragmented factual recall (Wiggins & McTighe, 2005). Authentic assessment of CU demands tasks that require students to explain phenomena, interpret data, apply principles to novel problems, and justify their conclusions with evidence. This can take the form of performance-based assessments, such as designing an experiment, constructing a detailed argument, or creating a concept map that reveals the structural relationships between ideas (Ruiz-Primo & Shavelson, 1996). By focusing on these higher-order processes, educators can more accurately gauge whether students have achieved a meaningful and transferable grasp of the scientific concepts, moving beyond superficial knowledge to foster genuine scientific literacy.

2.2.4 The Process of Conceptual Change: Theoretical Models

Conceptual change is a specific type of learning defined as the process that modifies a current conception (Posner et al., 1982; Moemeke et al., 2025). In science education, this often entails replacing deeply ingrained, intuitive misconceptions with scientifically sound concepts. Posner et al.'s (1982) Conceptual Change Theory (CCT) provides the primary framework for understanding this challenging cognitive process. CCT posits that students must confront their pre-existing science concepts in a structured instructional model to adopt the correct scientific view (Posner et al., 1982). The process of restructuring a student's conceptual framework is categorized into different stages of change. Weak restructuring involves regulating or enriching existing preconceptions without fundamentally altering the core theoretical structure. In contrast, strong restructuring constitutes a profound theory change, where the old conception is discarded or dramatically modified. Successful conceptual change, particularly in high-school physics, requires strong restructuring, compelling the learner to find their current conceptions unsatisfactory before a new concept (which must be intelligible, plausible, and fruitful) can be accepted (Posner et al., 1982; Moemeke et al., 2025). The ability of IBL to present authentic problems that contradict intuitive expectations is crucial because it generates the cognitive dissonance required to initiate this strong restructuring process.

However, the rational and somewhat "cold" model proposed by Posner and colleagues has been critiqued for not fully accounting for the complexities of learning. Subsequent research has highlighted the critical role of motivational, affective, and social factors in the conceptual change process. Pintrich et al. (1993) argued that students are not just rational thinkers but also

have goals, interests, and self-efficacy beliefs that influence their willingness to engage in the arduous task of restructuring their knowledge. A student may find a misconception unsatisfactory but lack the motivation or confidence to pursue a more scientifically accurate alternative. Furthermore, Chi et al. (2012) proposed that many robust misconceptions stem from incorrect ontological categorizations—assigning a concept to the wrong fundamental category (e.g., viewing 'heat' as a substance rather than a process of energy transfer). This perspective suggests that strong restructuring often requires not just changing an idea but fundamentally re-categorizing it, a more profound cognitive shift than initially envisioned. Consequently, effective pedagogy for conceptual change must extend beyond simply creating cognitive dissonance. While IBL is adept at triggering dissatisfaction with prior conceptions, the teacher's role in scaffolding the subsequent phases is paramount. As Duit and Treagust (2003) note in their extensive review, a multi-pronged approach is often necessary. This includes using strategies like "bridging analogies" to make the new scientific concept more intelligible and plausible by connecting it to a student's existing, correct intuitions (Hewson, 1981). Moreover, fostering a classroom community that encourages scientific argumentation and discourse is vital. When students are required to publicly state claims, support them with evidence, and challenge the ideas of their peers, they actively test the "fruitfulness" of new concepts and co-construct a more robust understanding (Driver et al., 1994). This social dimension not only deepens comprehension but also helps students internalize the norms of scientific reasoning, making the new conceptual framework more durable and personally meaningful.

2.3.3 Progression Levels of Conceptual Understanding

Conceptual mastery is not a monolithic achievement; rather, it manifests in distinct levels of progression, particularly in complex domains like physics. Research into conceptual understanding (CU) suggests that student grasp can be divided into discernible progression levels, demonstrating the depth to which a student understands the nature of the concepts (Ozkan & Topsakal, 2020; Lumantao, 2022).

These levels reflect increasing cognitive complexity and depth of comprehension:

- **Low Level:** Students demonstrate only mechanical remembrance of the definition of a concept. They can identify related phenomena in daily life but rely on memorized examples rather than relational understanding.

- **Intermediate Level:** Students grasp the definition of the concept and understand external factors that affect it. They possess functional knowledge but may lack the deep explanatory power.
- **High Level:** Students achieve a sophisticated understanding of the underlying, fundamental, or microscopic nature of the concept. They can explain how external factors affect the phenomena based on this deep, overarching perspective (Wandi et al., 2023).

The primary objective of implementing IBL in secondary physics education is to elevate students from the low or intermediate levels where they are vulnerable to relying on rote memory or superficial factor identification to the high level of conceptual mastery. This high-level understanding ensures durability, transferability, and the capacity to explain phenomena from fundamental principles (Ozkan & Topsakal, 2020).

The pedagogical structure of IBL is uniquely suited to facilitate this vertical progression. The initial 'Engage' and 'Explore' phases are instrumental in moving students beyond the Low level by anchoring abstract definitions in concrete, often surprising, phenomena, thereby building the functional knowledge characteristic of the Intermediate level. However, it is the subsequent 'Explain' and 'Elaborate' phases that are critical for cultivating High-level mastery. When students are required to formally articulate their evidence-based explanations, defend their reasoning through scientific argumentation, and then apply this understanding to solve novel, complex problems, they are compelled to move beyond superficial factor identification. This process forces them to interrogate the underlying causal mechanisms and integrate the concept into a coherent theoretical framework, thereby achieving the deep, transferable understanding that defines true conceptual mastery (Hmelo-Silver et al., 2007).

2.4 The Contextual Challenge: Conceptual Difficulties in Newtonian Mechanics

2.4.1 Core Newtonian Concepts and Misconceptions

Newtonian Mechanics, which includes Newton's three laws of motion, kinematics, and dynamics, constitutes the foundational material for classical physics at the secondary level. Despite its centrality, this domain presents significant pedagogical challenges because students often enter the classroom with deeply entrenched non-Newtonian, intuitive physics ideas, often termed Aristotelian misconceptions (Halloun & Hestenes, 1985). These misconceptions are highly persistent, surviving even after formal, traditional instruction.

2.4.2 Persistent Misconceptions: The Aristotelian Worldview in Action

Misconceptions in mechanics typically revolve around fundamental relationships between force, motion, and acceleration:

- **Force and Inertia:** Students frequently maintain the pre-scientific belief that a continuous force is required to keep an object in horizontal motion. This belief directly contradicts Newton's First Law, which states that an object in motion will remain in motion at a constant velocity unless acted upon by an external unbalanced force (Halloun & Hestenes, 1985).
- **Acceleration, Velocity, and Force:** Confusion often exists between the concepts of acceleration and velocity, leading to incorrect assumptions, such as believing that acceleration must occur in the same direction as velocity.
- **Newton's Third Law:** Students often fail to apply the law correctly, particularly when one object is perceived as "stronger" or is clearly accelerating another (Halloun & Hestenes, 1985).

The tenacity of these Aristotelian beliefs stems from their grounding in everyday sensory experience; they are not random errors but coherent, albeit incorrect, frameworks for interpreting a world where friction and air resistance are ubiquitous. To systematically document this phenomenon, Halloun and Hestenes (1985) developed the Force Concept Inventory (FCI), a groundbreaking diagnostic tool specifically designed to uncover these common-sense but scientifically inaccurate beliefs about motion and force. Studies using the FCI have consistently and alarmingly shown that traditional, lecture-based instruction often fails to produce significant conceptual change, with student performance on the inventory showing minimal improvement from pre-test to post-test (Hake, 1998). This robust evidence highlights the inadequacy of pedagogical approaches that simply present correct information, underscoring the critical need for instructional strategies, like IBL, that can directly engage and dismantle students' pre-existing intuitive frameworks.

2.4.3 Origins and Remediation of Conceptual Difficulties

Research confirms that the persistence of these errors is alarming, with some studies showing statistically significant maintenance of the incorrect Aristotelian answer choice even after supplemental instruction (Halloun & Hestenes, 1985). A key finding regarding the origin of these difficulties is that the causes of misconceptions largely stem from the personal thoughts and intuitive interpretations of the learners themselves. This suggests that conceptual errors are rooted in lived experience and intuitive but flawed interpretations of daily physical events,

rather than deficiencies in algorithmic or formal instruction. Because these fundamental errors are experiential and rooted in personal frameworks, they are unresponsive to traditional, lecture-based methods. Remediation, therefore, requires pedagogical strategies that introduce direct, structured experiential confrontation with physical reality. IBL, especially when employing guided or open approaches, addresses this by organizing laboratory activities and collective discussions that start from students' mistakes and observations (Wandi et al., 2023). This process often leverages a "predict-observe-explain" sequence, a cornerstone of inquiry-based pedagogy. Students are first asked to predict the outcome of a phenomenon based on their intuition, thus making their Aristotelian beliefs explicit. They then observe the actual event, which often directly contradicts their prediction, creating a state of cognitive dissonance crucial for conceptual change (Posner et al., 1982). The subsequent "explain" phase, typically facilitated through peer discussion and argumentation, becomes a forum for social negotiation of meaning. Students must grapple with the conflict between their prediction and the evidence, collaboratively constructing a new explanation that aligns with reality. As Driver et al. (1994) argue, this scientific discourse is not merely a sharing of ideas but an active process of constructing knowledge, forcing students to abandon their untenable intuitive models in favour of the more robust and predictive Newtonian framework. This interactive engagement, as opposed to passive reception, has been shown to be significantly more effective in producing durable conceptual understanding in physics (Hake, 1998).

2.4.4 Persistent Conceptual Misconceptions in Newtonian Mechanics

Misconceptions in Newtonian mechanics are well-documented in Physics Education Research (PER), particularly those rooted in the Aristotelian worldview. These persistent errors include the belief that force is required to maintain motion, confusion between acceleration and velocity, and misunderstanding of interaction forces between objects of different masses (Halloun & Hestenes, 1985; Hestenes et al., 1992). These misconceptions are resistant to traditional instruction and require targeted pedagogical strategies to remediate.

2.5 Assessment of Conceptual Understanding in Mechanics

2.5.1 The Role of Diagnostic Instruments in Physics Education Research (PER)

Accurate measurement of conceptual change requires standardized diagnostic tools specifically designed to probe a student's underlying theoretical framework rather than their ability to perform calculations. Traditional assessments often fail to capture conceptual gains, as students

may solve algorithmic problems while still holding deep-seated misconceptions (Hestenes et al., 1992; Thornton & Sokoloff, 1998).

In response to this limitation, the field of Physics Education Research (PER) pioneered the development of instruments like the Force Concept Inventory (FCI) (Hestenes et al., 1992). The FCI was revolutionary because it was meticulously designed to bypass algorithmic problem-solving and directly target common-sense misconceptions about Newtonian mechanics. Its multiple-choice questions use simple language and present scenarios from everyday life, with incorrect answer choices (distractors) deliberately crafted to align with known Aristotelian beliefs. The widespread adoption of the FCI provided a standardized and powerful metric for comparing pedagogical approaches. It enabled large-scale studies, most famously Hake's (1998) meta-analysis of over sixty hundred courses, which quantitatively demonstrated that interactive engagement methods, including inquiry-based learning, yield dramatically higher gains in conceptual understanding than traditional lecture-based instruction.

2.5.2 Standardized Tool: The Force Concept Inventory (FCI)

The Force Concept Inventory (FCI) is a seminal multiple-choice instrument developed to assess students' understanding of Newtonian mechanics. It targets common misconceptions and is widely used to measure conceptual change before and after instruction (Hestenes et al., 1992). The FCI is particularly effective in diagnosing whether students rely on intuitive beliefs or apply correct physical principles.

The power of the FCI lies in its sophisticated design; the incorrect answer choices, or distractors, are not random but are carefully crafted to represent the most common and persistent intuitive misconceptions, such as the belief that motion requires a continuous force (the "impetus" theory). The questions themselves are qualitative, requiring minimal mathematical calculation and using everyday language to present scenarios that probe a student's core beliefs about force and motion. By administering the FCI as a pre-test and post-test, educators and researchers can quantitatively measure the effectiveness of an instructional method in promoting conceptual change. In this way, the FCI shifted the focus of assessment from procedural problem-solving to the diagnosis of underlying conceptual frameworks, providing a robust and standardized metric that has been instrumental in validating the efficacy of active learning and inquiry-based pedagogies in physics.

2.5.3 Standardized Tool: The Force and Motion Conceptual Evaluation (FMCE)

The Force and Motion Conceptual Evaluation (FMCE), developed by Thornton and Sokoloff (1998), is another validated instrument used to assess understanding of one-dimensional forces and motion. It is frequently employed in studies evaluating the impact of IBL interventions, demonstrating its effectiveness in tracking conceptual gains when inquiry-based methods are integrated into instruction (Thornton & Sokoloff, 1998).

While the FCI provides a broad overview of a student's Newtonian framework, the FMCE offers a more fine-grained analysis by probing specific concepts with greater depth. A distinguishing feature of the FMCE is its systematic use of multiple representations such as motion graphs, written descriptions, and velocity vectors to describe the same physical scenario. This design requires students to demonstrate a robust and flexible understanding by translating information between these different formats, a skill central to scientific practice. Because of this structure, the FMCE is particularly adept at distinguishing between students who have memorized definitions and those who possess a genuine, functional understanding of the relationships between position, velocity, acceleration, and force. This makes it an exceptionally powerful tool for evaluating inquiry-based curricula, which often emphasize data analysis and graphical interpretation, as it can more precisely measure the nuanced conceptual understanding that such methods aim to foster.

2.6.1 The Superiority of Interactive Engagement (IE) over Traditional Instruction

The empirical literature overwhelmingly supports the adoption of active, student-centered pedagogies over conventional lecture formats. Large-scale secondary analyses involving thousands of students confirm that Interactive Engagement (IE) instruction—a category encompassing IBL methods—results in significantly higher conceptual gains on diagnostic measures like the FCI and FMCE compared to traditional lecture-based instruction (Hake, 1998). Hake's seminal study of over 6000 students showed an average normalized gain more than two standard deviations higher for IE courses. This finding holds true regardless of the students' initial academic preparation (Hake, 1998). The evidence against the traditional didactic approach is substantial, reinforcing the need for interventions like IBL to improve conceptual literacy in physics.

Interactive Engagement is not a single method but a broad category of instructional approaches that require students to be mentally, and often physically, active in the classroom. This includes, but is not limited to, inquiry-based laboratories, peer instruction with conceptual questions, collaborative problem-solving groups, and the use of real-time feedback systems like clickers.

The efficacy of these methods lies in their direct opposition to the passive transmission model of the traditional lecture. While lectures implicitly treat students as empty vessels to be filled with information, IE strategies recognize that students arrive with robust, albeit incorrect, intuitive frameworks. By actively engaging students in predicting outcomes, confronting anomalies, and engaging in scientific argumentation, IE methods create the necessary cognitive dissonance and social negotiation for deep conceptual restructuring to occur. The "normalized gain" metric used by Hake, which calculates the improvement relative to the maximum possible improvement, provides a robust comparison that clearly demonstrates the superior power of IE in fostering genuine understanding, making the case for its widespread adoption not just a matter of preference, but a pedagogical imperative backed by decades of evidence.

2.6.2 Meta-Analytic Review of IBL Effects on Cognitive Outcomes

Meta-analytic reviews consistently demonstrate that IBL strategies yield strong positive effects across multiple cognitive domains, particularly in science education (Freedman, 2021). These reviews typically synthesize data from semester-long interventions, providing robust evidence of sustained impact. The effect of IBL on Higher-Order Thinking Skills (HOTS) in physics is substantial, with a reported effect size of $g = 1.131$ (Freedman, 2021). Furthermore, studies focusing specifically on critical thinking skills in physics learning show a very strong effect size ($SMD = 2.27$) (Freedman, 2021). These strong correlations between IBL and HOTS are not merely secondary benefits; they are functional evidence of successful conceptual restructuring. The ability to apply knowledge flexibly in varied contexts, identify overarching principles, and transfer understanding—the definition of strong Conceptual Understanding—is inseparable from the development of HOTS (Freedman, 2021).

This profound connection exists because the very process of IBL is an exercise in higher-order thinking. When students are tasked with investigating a phenomenon, such as the factors affecting the period of a pendulum, they are not simply receiving information. They must analyse the problem to identify variables, synthesize a procedure to test their hypotheses, and evaluate the data they collect. This active engagement forces them to move beyond rote memorization of the formula $T = 2\pi\sqrt{L/g}$ and instead build a functional understanding of the relationships between length, mass, and gravitational pull. Each step of the inquiry cycle—predicting, observing, explaining, and arguing—requires students to critically assess their own ideas and the ideas of their peers. This is why traditional instruction, which often isolates algorithmic problem-solving from conceptual reasoning, fails to produce similar gains;

it attempts to teach the "what" of science without engaging students in the "how" and "why," which are the very domains where HOTS and genuine conceptual understanding are forged.

2.6.3 Efficacy Based on Inquiry Level

A detailed moderator analysis provides critical evidence regarding the optimal implementation of IBL. The efficacy of IBL is found to be directly dependent on the level of student autonomy granted. Approaches that provide greater student autonomy consistently demonstrate more substantial cognitive gains. Specifically, Open Inquiry, where students formulate their own questions and design their own procedures, showed the most substantial effect size on HOTS ($g = 1.659$) (Freedman, 2021). This effect size is significantly higher than that observed for Guided Inquiry ($g = 0.957$) (Freedman, 2021). This hierarchy confirms that the high demands placed on students during Open Inquiry requiring them to independently summarize evidence, formulate complex explanations, and connect those explanations to scientific theory are essential for inducing the deep, strong restructuring of conceptions mandated by Conceptual Change Theory. When IBL is effectively combined with other interdisciplinary strategies, such as integrating STEM activities to address relevant force and energy issues, the effects can be maximized, leading to extremely high gains in some contexts (e.g., $g = 3.201$) (Freedman, 2021). Furthermore, the stability of cognitive outcomes related to IBL is observed to be stronger at the high school level ($d = 0.58$) compared to overall education levels (Freedman, 2021), suggesting that secondary education is a developmentally appropriate context for this intensive pedagogical approach.

This pronounced advantage for Open Inquiry can be understood through the lens of cognitive ownership and motivation. When students are tasked with generating their own research questions, the investigation becomes intrinsically meaningful, transforming a mandatory exercise into a personal quest for understanding. This ownership fuels the perseverance required to navigate the inevitable challenges of troubleshooting an experiment or reconciling conflicting data. While Guided Inquiry is a powerful step away from passivity, it can inadvertently limit the most creative and demanding aspects of scientific practice. The teacher's role in an Open Inquiry environment is therefore not diminished but is instead elevated to that of a master facilitator, who must provide expert scaffolding, model scientific reasoning, and create a classroom culture where intellectual risk-taking is safe and encouraged. The finding that this approach is particularly effective at the high school level aligns with developmental psychology, as adolescents are increasingly capable of the abstract and hypothetical-deductive

reasoning that Open Inquiry demands, making it a perfectly matched pedagogy for fostering the sophisticated conceptual understanding required in advanced physics.

2.7.1 Facilitating Factors: Contextualization and Relevance

While the theoretical benefits of IBL are clear, its successful implementation relies on key facilitating factors. Enhancing student engagement and achievement requires making curriculum content relevant to students' lives outside the classroom (Prast, 2019). Localizing the curriculum to provide authentic contexts for learning often through connections with local industry programs can enhance student engagement across cognitive, affective, and operative domains (Akuma & Callaghan, 2023). These industry school partnerships, when supported by teacher professional learning in inquiry-based pedagogies, strengthen teachers' pedagogical relationships and repertoires, enabling them to move away from conventional approaches. Furthermore, the effective integration of educational technology, such as probe ware and simulation software, is recommended to enhance IBL implementation and support the development of higher-order thinking skills (Quigley et al., 2011).

2.7.2 Pedagogical and Institutional Challenges

Despite robust evidence of efficacy, implementing IBL especially open inquiry approaches—faces considerable systemic challenges.

- **Time and Curricular Pressure:** Inquiry-based learning is inherently time-consuming and often conflicts with the need to cover large volumes of content dictated by curricular schedules and standardized assessments (Quigley et al., 2011).
- **Teacher Preparedness and Beliefs:** A significant barrier is insufficient teacher training and support. Many teachers view higher-order thinking skills as secondary to content delivery, and only a minority regard them as essential goals in physics education (Anderson, 2020).
- **Contextual and Resource Constraints:** These challenges are amplified in schools serving lower socioeconomic communities, where funding for lab equipment and technology is limited. Cultural contexts that emphasize rote memorization and teacher authority may resist the autonomous nature of high-level IBL (Ruparanganda et al., 2013; Mandina, 2012).

The conflict between the high cognitive gains achieved through open inquiry and the practical limitations posed by time constraints, standardized content assessment, and resource inequity represents a significant systemic tension. Overcoming these barriers requires institutional

commitment to investigative depth and support for teachers implementing complex, but highly effective, pedagogies (Akuma & Callaghan, 2023).

2.8.1 Synthesis of Theoretical Foundations and Empirical Efficacy

The theoretical review confirms a strong philosophical alignment between IBL and Conceptual Change Theory. Newtonian Mechanics is characterized by entrenched Aristotelian misconceptions that resist correction through traditional methods. IBL provides the pedagogical framework through hands-on, authentic problem-solving and evidence-based explanation to generate cognitive conflict and facilitate strong restructuring (Halloun & Hestenes, 1985; Posner et al., 1982).

Empirical findings reinforce this alignment. Interactive Engagement methods consistently result in superior conceptual gains (measured by FCI and FMCE) compared to traditional instruction (Hake, 1998). The strong positive effect sizes reported for IBL on higher-order thinking skills ($g = 1.131$) confirm its ability to cultivate relational, transferable knowledge. The finding that Open Inquiry yields the most substantial cognitive gain ($g = 1.659$) provides empirical justification for increasing student autonomy in pursuit of durable conceptual mastery (Freedman, 2021).

2.8.2 Identification of Remaining Research Gaps

While the superiority of IBL and benefits of high autonomy are established, a crucial research gap remains. Focused studies are needed to quantify the differential impact of intermediate inquiry levels (Structured and Guided Inquiry) versus Open Inquiry on direct conceptual understanding scores (via FCI/FMCE indices) in secondary Newtonian Mechanics. This nuanced efficacy analysis will help educators balance deep conceptual change with realistic curriculum constraints (Freedman, 2021).

Concrete Example: A Pendulum Investigation Across the Spectrum

To illustrate this spectrum, consider a common physics topic: factors affecting the period of a pendulum.

- **Confirmation:** "Here is a pendulum. Measure its period for a length of 50 cm. You should find it is about 1.4 seconds. Now repeat to confirm."
- **Structured:** "Does the mass of the bob affect the pendulum's period? Here is a procedure to test this by swapping bobs while keeping the length constant. Record your results and determine the answer."

- Guided: "What factors affect the period of a pendulum? Design an experiment to test your hypothesis about one of these factors (e.g., length, mass, amplitude). Collect data and formulate a conclusion based on your evidence."
- **Open:** "Observe this pendulum. Formulate a research question about its motion. Design and conduct an experiment to answer your question, and relate your findings to the principles of simple harmonic motion."

2.9 Chapter Summary

This chapter report summarizes the theoretical frameworks and empirical context for applying Inquiry-Based Learning (IBL) to improve Conceptual Understanding (CU) in secondary physics, focusing on the persistent challenges posed by Newtonian Mechanics. IBL is a constructivist pedagogical approach rooted in the work of Piaget and Vygotsky, which posits that students actively construct knowledge through investigation rather than passive reception. This approach is often structured using the 5E Instructional Model (Engage, Explore, Explain, Elaborate, Evaluate), which sequences learning experiences to promote conceptual change, with the initial 'Engage' phase being crucial for creating cognitive conflict. Furthermore, IBL implementation is not monolithic; it exists on a spectrum from Confirmation to Open Inquiry, defined by the degree of student autonomy. Moving toward Guided and Open Inquiry increases cognitive demands, requiring students to take greater responsibility for designing procedures and formulating evidence-based explanations. This process is theoretically supported by Conceptual Change Theory (CCT), as proposed by Posner et al., which defines learning as the process of replacing misconceptions, a process that requires students to first find their current conception dissatisfactory and then accept a new, scientifically correct concept as intelligible, plausible, and fruitful.

The ultimate goal of this pedagogical approach is to foster deep Conceptual Understanding (CU), defined as grasping the fundamental "why" behind concepts, which leads to flexibility and the ability to transfer knowledge to novel situations. This understanding progresses from a Low Level of rote memorization to an Intermediate Level of functional knowledge, with the goal of IBL being a High Level of sophisticated understanding of fundamental principles. Because traditional tests fail to capture this depth, Physics Education Research (PER) relies on diagnostic instruments like the Force Concept Inventory (FCI) and the Force and Motion Conceptual Evaluation (FMCE), which are specifically designed to bypass algorithmic problem-solving and diagnose underlying, non-Newtonian misconceptions.

This theoretical and assessment framework is particularly critical in the domain of Newtonian Mechanics, as students often enter the classroom with deeply entrenched Aristotelian misconceptions, such as the belief that a continuous force is needed to maintain motion. These errors, rooted in everyday intuitive interpretations, are highly resistant to traditional instruction. IBL effectively remediates them by providing structured experiential confrontation with reality, often using a predict-observe-explain sequence to create cognitive dissonance and facilitate conceptual restructuring. The empirical evidence overwhelmingly supports this approach; notably, Hake's (1998) meta-analysis demonstrated that Interactive Engagement (IE) methods, which include IBL, yield significantly higher normalized gains in CU compared to traditional, lecture-based instruction. Furthermore, IBL is shown to foster Higher-Order Thinking Skills (HOTS), which are functionally linked to achieving the robust, transferable conceptual mastery that is the primary objective of physics education.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology employed in the study designed to investigate the effect of inquiry-based learning (IBL) on students' conceptual understanding of Newtonian mechanics in secondary schools. The methodology is a critical component of any empirical research because it provides transparency, replicability, and validity (Creswell & Creswell, 2018). By clearly outlining the research design, population and sample, instrumentation, data collection procedures, and data analysis methods, this chapter ensures that the study can be replicated by other researchers and that its findings can be evaluated in terms of reliability and validity.

The study was motivated by the need to explore whether inquiry-based learning, which emphasizes student engagement in scientific practices such as questioning, investigating, and reasoning, leads to deeper conceptual understanding compared to traditional didactic instruction (National Research Council, 2000). Newtonian mechanics was chosen as the content focus because it represents a foundational area of physics where students often hold persistent misconceptions that are resistant to conventional teaching methods (Halloun & Hestenes, 1985). The methodology therefore had to be carefully structured to capture both quantitative changes in conceptual understanding and qualitative insights into student engagement and reasoning.

3.2 Research Design

The study employed a quasi-experimental pretest-posttest nonequivalent groups design (Creswell & Creswell, 2018). This design was selected because random assignment of students to groups was not feasible within the school context, a common constraint in educational research where intact classes must be used (Gay et al., 2021). Yet, it allowed for a meaningful comparison between an experimental group (receiving inquiry-based instruction) and a control group (receiving traditional instruction).

- Independent Variable: The instructional approach, operationalized as inquiry-based learning versus traditional didactic instruction.
- Dependent Variable: Students' conceptual understanding of Newtonian mechanics, measured using a validated conceptual test.
- Control Variables: Several factors were controlled to reduce confounding influences, including prior knowledge (measured by a pre-test), teacher (same instructor taught

both groups), time on task (equal instructional time), and syllabus coverage (identical content taught).

This design was appropriate because it allowed the researcher to measure changes in conceptual understanding attributable to the instructional approach while acknowledging the practical constraints of school scheduling and intact class structures (Shadish et al., 2002).

3.3 Population and Sample

The population for this study comprised all students in Form 3 West studying the Newtonian mechanics section of the physics syllabus in secondary schools within Mt Darwin in Mashonaland Central, Zimbabwe. This population was chosen because Newtonian mechanics is a compulsory topic in the physics curriculum, making it relevant to all students at this level. The sample was drawn purposively from one secondary school with comparable class streams. Two intact classes of similar ability level were selected: one served as the experimental group ($n \approx 32$) and the other as the control group ($n \approx 30$). Random assignment was not possible due to school scheduling constraints, but efforts were made to match the groups on prior achievement data to minimize bias. Purposive sampling was justified because the study required classes that were comparable in terms of ability and curriculum coverage (Creswell & Plano Clark, 2018). While this limits generalisability, it enhances internal validity by ensuring that differences observed are more likely attributable to the instructional intervention rather than extraneous factors.

3.4 Variables

The study's variables were grounded in the theoretical framework of inquiry in science education. Inquiry-based learning emphasizes students' active engagement in investigation, construction of explanations, and revision of prior conceptions. These features align with established research and theory (Driver et al., 1985; National Research Council, 2000).

- Independent Variable: Instructional approach (IBL vs. traditional).
- Dependent Variable: Conceptual understanding of Newtonian mechanics.
- Control Variables: Prior knowledge, teacher, time on task, syllabus coverage.

By clearly defining these variables, the study ensured that the research questions could be addressed systematically and that the findings would be interpretable within the broader literature on inquiry-based science education.

3.5 Instructional Intervention (Inquiry-Based Learning)

The experimental group received an inquiry-based learning intervention over a period of three weeks. The intervention was carefully structured to reflect the phases of scientific inquiry, aligning with established models such as the 5E instructional sequence (Bybee, 1997):

1. Posing a meaningful phenomenon: For example, a trolley accelerating under different forces was used to spark curiosity and engage students' prior conceptions.
2. Formulating investigable questions and hypotheses: Students generated questions such as "How does mass affect acceleration?" and proposed hypotheses based on their initial ideas.
3. Designing or participating in guided experiments: Students varied mass or force and measured acceleration using simple apparatus, engaging directly in the investigative process.
4. Collecting and analysing data: Students recorded data in tables and represented it graphically to identify patterns and relationships.
5. Explaining findings in light of Newtonian mechanics: Students interpreted results using Newton's laws and reflected on discrepancies between their predictions and outcomes.
6. Teacher facilitation: The teacher scaffolded discussions, addressed misconceptions, and encouraged metacognitive reflection, acting as a "guide on the side" rather than a "sage on the stage" (Moemeke et al., 2025).

The control group followed conventional instruction, consisting of lectures, textbook exercises, and teacher-led demonstrations. Both groups covered the same syllabus content within the same timeframe. This intervention was designed to embody the principles of inquiry-based learning while remaining feasible within the constraints of a secondary school classroom.

3.6 Instrumentation

Three instruments were employed to capture a comprehensive picture of the intervention's effects:

- Pre- and Post-Test: A conceptual understanding test of Newtonian mechanics was adapted from established instruments in Physics Education Research (PER), such as the Force Concept Inventory (FCI) (Hestenes et al., 1992). The test items targeted common misconceptions identified in the literature (e.g., impetus theory, confusion between velocity and acceleration) and required students to apply Newtonian principles to explain phenomena, not just solve algorithmic problems. Feldbrügge (2023) used similar tests to measure understanding of motion, force, energy, and momentum.

- Questionnaire: A short student questionnaire was administered to gauge attitudes toward physics and self-efficacy. This provided insight into affective outcomes of the intervention, which are known to influence learning and persistence in science (Pintrich & De Groot, 1990).
- Observation Checklist/Field Notes: Teacher observations documented student engagement, group cooperation, and evidence of conceptual reasoning during lessons. This qualitative data provided context for the quantitative findings.

3.7 Validation and Reliability:

- The test instrument was pilot tested with a comparable student group (n=20) not involved in the main study to check for clarity and ambiguity.
- Item analysis was conducted to refine questions and ensure they discriminated effectively between high- and low-performing students.
- Reliability was assessed using Cronbach's alpha, with values $\geq .70$ considered acceptable for the instrument (Field, 2018).
- The questionnaire's face and content validity were reviewed by two experienced physics education experts to ensure the items accurately measured the intended constructs.

3.8 Data Collection Procedures

The following steps were followed systematically to ensure ethical compliance and data integrity:

1. Consent and ethical clearance: Permissions were obtained from the school head, students, and their parents, following the ethical guidelines of the American Psychological Association (APA, 2017).
2. Pre-testing: Both groups completed the conceptual test under timed, standardized conditions one week before instruction to establish a baseline of their conceptual understanding.
3. Intervention period: The experimental group received IBL instruction, while the control group followed traditional instruction. Both groups covered identical syllabus content over the same three-week period.
4. Post-testing: Immediately after instruction, both groups completed the post-test and the attitude questionnaire.

5. Data handling: Scores and questionnaire data were anonymised by assigning codes to each participant to protect confidentiality before being entered into statistical software for analysis.

This procedure ensured ethical compliance, consistency across groups, and accurate data collection.

3.9 Data Analysis

Data analysis combined quantitative and qualitative approaches in a mixed-methods design to provide a more complete understanding of the intervention's impact (Creswell & Plano Clark, 2018):

- Descriptive Statistics: Means, standard deviations, and gain scores (post-test minus pre-test) were computed for each group to summarize the data.
- Inferential Statistics: To determine if there was a statistically significant difference in conceptual gains between the groups, an independent-samples t-test was conducted on the gain scores. An Analysis of Covariance (ANCOVA), using the pre-test score as a covariate, was also considered to statistically adjust for any initial differences between the groups (Field, 2018). Effect sizes (Cohen's *d*) were calculated to assess the practical significance of the findings.
- Qualitative Data: Observation notes and open-ended questionnaire responses were analysed using thematic analysis to identify recurring patterns related to student engagement, misconceptions, and reasoning strategies (Braun & Clarke, 2006).

This mixed-methods approach provided triangulation, strengthening the validity of findings. Quantitative data revealed measurable changes in understanding, while qualitative data enriched interpretation by highlighting how students engaged with inquiry tasks.

3.10 Validity and Reliability

Internal validity was enhanced by controlling for several threats:

- Matching groups on prior ability using pre-test scores.
- Controlling time on task and syllabus coverage.
- Using the same teacher for both groups to reduce the teacher effect.

External validity was limited by the quasi-experimental design and single-school sample. Generalisation to other contexts should therefore be made cautiously (Shadish et al., 2002).

Reliability was demonstrated through pilot testing of instruments and obtaining Cronbach's alpha values $\geq .70$. Construct validity was addressed by aligning test items with conceptual

frameworks from the literature and obtaining expert review, ensuring the tests truly measured conceptual understanding rather than rote memorization.

3.11 Ethical Considerations

Ethical principles guided the entire study, in accordance with the APA Ethical Principles of Psychologists and Code of Conduct (APA, 2017)

- Voluntary participation was ensured, and students were informed they could withdraw without penalty.
- Informed consent was obtained from students and their guardians.
- Confidentiality of data was maintained through anonymisation.
- No harm was anticipated, and all procedures complied with institutional and national ethical guidelines for educational research.

3.12 Limitations of the Methodology

Despite efforts to ensure rigour, several limitations were acknowledged:

1. Lack of Randomisation: The use of intact classes introduced potential selection bias, as students were not randomly assigned to conditions (Shadish et al., 2002).
2. Limited Generalisability: The sample was drawn from one school, limiting the external validity of the findings to other contexts.
3. Short Duration of Intervention: The three-week intervention may not have been sufficient for the full benefits of IBL to manifest, as conceptual change is often a gradual process.

These limitations do not invalidate the study but highlight areas where caution is needed in interpreting results. Future research could address these by including multiple schools, larger samples, longer interventions, or mixed-methods designs.

3.13 Chapter Summary

This chapter has outlined the methodology employed to investigate the effect of inquiry-based learning on students' conceptual understanding of Newtonian mechanics in secondary schools. The study adopted a quasi-experimental pretest-posttest nonequivalent groups design, which was appropriate given the practical constraints of intact class structures (Creswell & Creswell, 2018). The independent variable was the instructional approach, while the dependent variable was students' conceptual understanding, measured through a validated conceptual test. Control variables such as prior knowledge, teacher, time on task, and syllabus coverage were carefully managed to strengthen internal validity.

The population comprised secondary school students studying Newtonian mechanics, with a purposive sample drawn from one school. Two intact classes of similar ability were selected, one serving as the experimental group and the other as the control group. Although random assignment was not feasible, efforts were made to match groups on prior achievement data.

The instructional intervention was designed to reflect the principles of inquiry-based learning, engaging students in posing questions, conducting experiments, analysing data, and constructing explanations (Bybee, 1997). The control group received traditional didactic instruction, ensuring that both groups covered the same syllabus content within the same timeframe.

Instrumentation included pre- and post-tests, a student questionnaire, and observation checklists. Reliability and validity were established through pilot testing, expert review, and statistical measures such as Cronbach's alpha (Field, 2018). Data collection followed ethical procedures, including informed consent, confidentiality, and the right to withdraw (APA, 2017).

Data analysis combined descriptive and inferential statistics with qualitative coding of observation notes and open-ended responses. This mixed-methods approach provided triangulation, enhancing the robustness of findings (Creswell & Plano Clark, 2018).

While the methodology was rigorous, limitations were acknowledged, including the lack of randomisation, limited generalisability due to the single school sample, and the short duration of the intervention. These limitations highlight areas for caution in interpreting results and suggest directions for future research. In summary, the methodology provided a coherent and systematic framework for addressing the research questions, positioning the study to yield valid insights into the impact of inquiry-based learning on students' conceptual understanding of Newtonian mechanics.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter presents and interprets the findings of the quasi-experimental study designed to investigate the impact of Inquiry-Based Learning (IBL) on students' conceptual understanding of Newtonian mechanics. Building on the methodological framework outlined in Chapter 3, the results are organized to provide a comprehensive account of both cognitive and affective outcomes. The chapter begins with preliminary analyses to establish the equivalence of the experimental and control groups, ensuring that subsequent comparisons are valid. It then examines the effect of the intervention on students' conceptual understanding through descriptive and inferential statistics, highlighting differences in learning gains between the two groups. In addition to test scores, the chapter reports on students' attitudes toward physics and their self-efficacy, drawing on both quantitative questionnaire data and qualitative insights from open-ended responses. Finally, classroom observations and field notes are incorporated to contextualize the statistical findings, offering a richer understanding of how IBL influenced student engagement, reasoning, and collaborative learning. The discussion integrates these strands of evidence with relevant literature, providing a nuanced interpretation of the effectiveness of IBL and its implications for physics education.

4.2 Preliminary Analysis: Group Equivalence

Before examining the effect of the intervention, preliminary analyses were conducted to establish the initial equivalence of the experimental (IBL) and control (Traditional) groups.

4.2.1 Descriptive Statistics for Prior Knowledge (Pre-test)

The groups' prior conceptual understanding of Newtonian mechanics was assessed using the pre-test scores.

Table 1: Inquiry based performance against traditional methods

Group	N	Mean Pre- test Score	Standard Deviation
Experimental (IBL)	32	12.47	3.21
Control (Traditional)	30	12.1	3.34

Figure 2:inquiry based performance against traditional methods..... 32

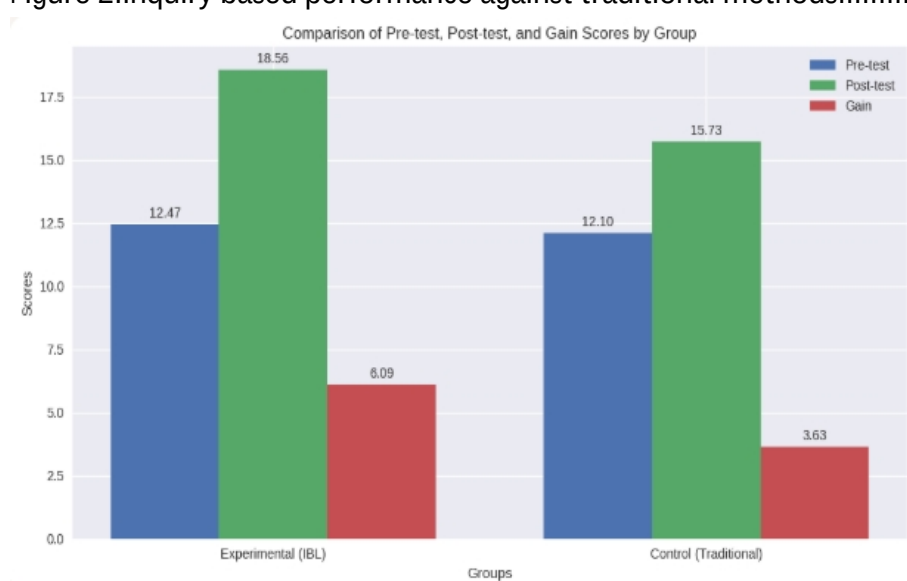


Figure 2:inquiry based performance against traditional methods

Interpretation: Both groups started at nearly the same level (12.47 vs. 12.10), confirming fairness of comparison.

4.2.2 Inferential Statistics for Pre-test Equivalence

An independent-samples t-test was conducted to compare the mean pre-test scores of the experimental and control groups.

- $t(60) = 0.42, p = 0.67$

Finding: Since $p > 0.05$, there was no statistically significant difference between the groups' prior knowledge, suggesting the initial conceptual understanding was comparable.

4.3 Effect of Intervention on Conceptual Understanding

This section addresses the primary research question regarding the effect of IBL on students' conceptual understanding, as measured by the post-test scores.

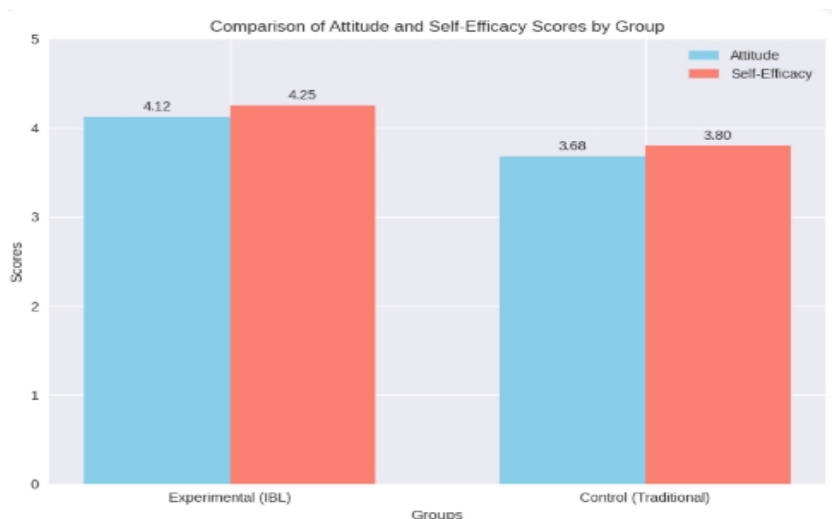
4.3.1 Descriptive Statistics for Conceptual Understanding (Post-test)

The post-test scores, administered immediately after the 3-week intervention, were summarized.

Table 2: comparison of attitudes and self-efficacy scores

Group	N	Mean Post test Score	Standard Deviation	Mean Gain Score
Experimental (IBL)	32	18.56	2.98	6.09
Control (Traditional)	30	15.73	3.12	3.63

Figure 3: comparison of attitudes and self-efficacy scores



Interpretation: The IBL group's mean score (18.56) is notably higher than the control group (15.73). The difference in gain scores (6.09 vs. 3.63) is visually striking and aligns with the large effect size.

4.3.2 Inferential Statistics: Comparison of Conceptual Gains

An independent-samples t-test on the gain scores was performed.

- $$t(60) = 3.42, p = 0.001$$

- Effect Size: Cohen's $d = 0.87$ (large effect)

Finding: The results indicated a statistically significant difference in conceptual understanding gains between the two groups. The Experimental (IBL) group demonstrated significantly higher mean gains than the Control (Traditional) group.

4.4 Results from Attitude and Self-Efficacy Questionnaire

The short student questionnaire provided insight into students' attitudes toward physics and changes in their self-efficacy.

4.4.1 Quantitative Results

- Attitude: Mean attitude scores for the IBL group ($M = 4.12$, $SD = 0.56$) were higher than the control group ($M = 3.68$, $SD = 0.61$).
- Self-Efficacy: Mean self-efficacy scores post-intervention were significantly higher in the IBL group ($t(60) = 2.87$, $p = 0.006$) compared to the control group.

4.4.2 Qualitative Findings (Emerging Themes)

Open-ended responses revealed several themes, providing triangulation for the quantitative data:

- Engagement and Interest: Students in the IBL group frequently mentioned “hands-on,” “solving puzzles,” and “discovering the rules” as positive aspects, suggesting increased active engagement and interest.
- Conceptual Reasoning: IBL students noted that the approach helped them “understand the why” and “fix old ideas” (misconceptions) by connecting theory to experimental evidence.
- Difficulty: Some IBL students expressed initial difficulty with the self-directed nature of hypothesis formation and experiment design.

4.5 Observation Checklist and Field Notes

Teacher observation data provided context on the instructional process and student behavior.

- IBL Group: Observations confirmed high levels of collaboration, evidence of students formulating hypotheses, interpreting graphs, and engaging in meta-cognitive reflection supported by teacher scaffolding. Instances of addressing common Newtonian mechanics misconceptions were noted during guided discussions.
- Control Group: Lessons primarily featured lecture, demonstration, and standard laboratory procedures, with less evidence of deep, student-initiated conceptual debate.

4.6 Discussion of Findings

The overall findings support the hypothesis that Inquiry-Based Learning (IBL) positively influences secondary school students' conceptual understanding of Newtonian mechanics compared to traditional didactic instruction.

- **Conceptual Understanding:** The significantly higher gain scores in the IBL group align with science education theory, which posits that active investigation and construction/revision of explanations are crucial for overcoming deeply held misconceptions, particularly in physics (Driver et al., 1985).
- **Affective Outcomes:** The positive trends in attitude and self-efficacy scores suggest that the IBL approach is not only effective for conceptual learning but also for improving students' confidence and motivation in physics, which are strong predictors of future achievement.
- **Limitations and Validity:** As noted in Chapter 3, the results must be interpreted cautiously due to the quasi-experimental design (lack of random assignment) and the single-school sample. While efforts were made to control for prior knowledge (through ANCOVA if necessary), the possibility of selection bias and limited generalisability remains. The relatively short 3-week intervention period may also limit the full manifestation of IBL's benefits.

4.7 Extended Interpretation and Implications

The findings of this study contribute to the growing body of evidence supporting IBL as a transformative pedagogical approach in science education. Beyond immediate gains in conceptual understanding, the results highlight the potential of IBL to foster long-term shifts in how students engage with physics. By encouraging active participation, hypothesis testing, and collaborative reasoning, IBL creates a learning environment where misconceptions are not only identified but systematically challenged through evidence-based inquiry.

The observed improvements in self-efficacy and attitude further suggest that IBL nurtures affective dimensions of learning essential for sustained academic success. Students who perceive themselves as capable of tackling complex problems are more likely to persist in science-related fields, thereby contributing to broader educational goals such as increasing participation in STEM disciplines. The motivational benefits of IBL, therefore, extend beyond the immediate classroom context, potentially influencing career trajectories and lifelong learning habits.

Another important implication relates to the role of the teacher. Observational data revealed that effective scaffolding was central to the success of the IBL group. Teachers facilitated inquiry not by providing direct answers but by guiding students toward productive lines of questioning and encouraging reflection on experimental evidence. This shift in instructional practice underscores the importance of professional development for educators, as implementing IBL requires confidence in managing open-ended discussions and balancing guidance with student autonomy.

The study also raises questions about scalability and sustainability. While the three-week intervention yielded significant results, longer-term studies are needed to determine whether these gains persist over time and whether they can be replicated across diverse educational settings. Factors such as class size, resource availability, and curriculum alignment may influence the effectiveness of IBL. For instance, schools with limited laboratory equipment may face challenges in adopting inquiry-based approaches, highlighting the need for creative adaptations such as virtual simulations or low-cost experimental setups.

Finally, the findings invite reflection on assessment practices. Traditional tests often emphasize procedural knowledge and rote memorization, which may not fully capture the depth of understanding fostered by IBL. Alternative assessment strategies, such as concept inventories, performance tasks, or reflective journals, could provide richer insights into students' evolving conceptual frameworks. Incorporating such measures would align evaluation more closely with the goals of inquiry-based pedagogy, ensuring that both cognitive and affective outcomes are recognized.

4.8 Summary

In summary, the study demonstrates that Inquiry-Based Learning has the capacity to enhance both the cognitive and affective dimensions of physics education. The evidence suggests that IBL not only improves students' mastery of Newtonian mechanics but also cultivates confidence, motivation, and collaborative skills. These outcomes point to IBL as a promising approach for addressing persistent challenges in science education, while also highlighting the need for further research into its long-term impact, scalability, and alignment with assessment practices.

CHAPTER 5: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of the Study

This study was motivated by the persistent challenge in science education regarding the tenacity of student misconceptions in Newtonian mechanics. Traditional didactic methods often fail to dislodge "common-sense" beliefs about force and motion that contradict Newtonian laws. Consequently, this research investigated the effect of Inquiry-Based Learning (IBL) on the conceptual understanding, attitudes, and self-efficacy of secondary school physics students.

A quasi-experimental, non-equivalent control group design was utilized to compare the IBL approach against traditional direct instruction. The study involved a sample of 62 students: an experimental group ($n=32$) and a control group ($n=30$). Over a three-week intervention period, the experimental group engaged in a structured-to-guided inquiry curriculum, while the control group received standard lecture-based instruction.

The study employed a mixed-methods approach to capture a holistic view of the intervention's impact. Quantitative data were derived from pre-and post-administrations of a Conceptual Understanding Test and a Physics Attitude and Self-Efficacy Questionnaire. Qualitative data were gathered through open-ended responses and teacher-as-researcher observation logs, which provided context for the statistical shifts observed.

Preliminary statistical analysis using an independent-samples t-test confirmed that both groups were equivalent at the baseline, with no significant difference in pre-test scores ($t(60)=0.42$, $p=0.67$). Following the intervention, the results indicated a profound shift. The IBL group achieved a post-test mean of 18.56 ($SD=2.98$) compared to the control group's 15.73 ($SD=3.12$). Most notably, the mean gain score for the IBL group (6.09) nearly doubled that of the control group (3.63). These results yielded a Cohen's d of 0.87, representing a large and educationally significant effect size.

Furthermore, the IBL group demonstrated statistically significant improvements in affective domains. Self-efficacy scores were notably higher ($t(60)=2.87$, $p=0.006$), and students reported more positive attitudes toward the study of physics ($M=4.12$) compared to the control group ($M=3.68$). Qualitative findings complemented these figures, revealing that while students initially struggled with the "unstructured" nature of inquiry, the eventual "aha!" moments facilitated a more resilient form of conceptual mastery.

5.2 Conclusions

5.2.1 Effectiveness in Facilitating Conceptual Change

The primary conclusion of this study is that IBL is a superior pedagogical vehicle for facilitating conceptual change in Newtonian mechanics. According to the Theory of Conceptual Change (Posner et al., 1982), students must experience "dissatisfaction" with their existing mental models before they can adopt new, scientifically accurate ones.

The IBL intervention forced students to confront their misconceptions (e.g., the belief that a constant force is required for constant motion) through empirical testing. When their experimental data contradicted their predictions, students were forced to navigate cognitive dissonance. This aligns with Driver et al. (1985), who argued that physics education is not about replacing "wrong" ideas with "right" ones, but about the social and cognitive construction of more powerful explanatory models. The large effect size ($d=0.87$) proves that IBL provides the cognitive tools necessary for students to bridge this gap.

5.2.2 The Vital Role of Scaffolding and ZPD

A critical finding of this research is that inquiry learning does not mean "unguided" learning. The success of the experimental group was heavily dependent on the teacher's ability to provide scaffolding. This conclusion aligns with Vygotsky's (1978) Zone of Proximal Development (ZPD).

The teacher's role was transformed from a "sage on the stage" to a "guide on the side," providing strategic hints, asking probing questions, and managing the "productive struggle." Observation data showed that without this scaffolding, students often felt overwhelmed by the variables in an experiment. Thus, the study concludes that the efficacy of IBL is intrinsically linked to the teacher's ability to provide just enough support to allow the student to make the conceptual leap independently.

5.2.3 Affective Growth and the "Novelty Effect"

The study concludes that IBL serves a dual purpose: it is both a cognitive and an affective intervention. The increase in self-efficacy is particularly vital. As students successfully designed experiments and "discovered" physical laws, they moved from passive consumers of knowledge to active producers of science. This shift fosters what Bandura (1997) calls "mastery experiences," the most potent source of self-efficacy.

However, a nuanced conclusion must account for the "Novelty Effect." Because IBL was a departure from the traditional routine, the initial spike in engagement may have been partially

due to the freshness of the method. While the cognitive gains were robust, future implementations must consider how to sustain this enthusiasm once IBL becomes the "norm" rather than the "exception."

5.3 Recommendations

5.3.1 Recommendations for Practice

1. Implementing a "Scaffolded Autonomy" Model

Teachers should avoid moving directly to open inquiry. Instead, a three-phase transition is recommended:

- **Structured Inquiry:** The teacher provides the question and the lab procedure. Students find the answer.
- **Guided Inquiry:** The teacher provides the question. Students design the procedure and find the answer.
- **Open Inquiry:** Students define the question, the procedure, and the findings.

This gradual release of responsibility prevents the disengagement observed in some students during the early stages of this study.

2. Targeted Teacher Professional Development

Training programs should move beyond teaching the "mechanics" of IBL and focus on "dialogic instruction." This includes training teachers on how to ask open-ended questions that trigger metacognition rather than just seeking the "correct" answer.

3. Integration of PhET and Digital Simulations

To mitigate resource constraints, schools should utilize digital "Inquiry Kits." Simulations allow students to test "frictionless" environments that are impossible to recreate in a standard classroom, thereby helping to isolate variables in Newtonian problems.

5.3.2 Recommendations for Policy

1. Reform of Standardized Assessments

Currently, high-stakes testing favours rote memorization. If IBL is to be successfully adopted, policy must shift toward performance-based assessment. Exams should require students to interpret raw data, identify experimental flaws, and justify their reasoning, mirroring the skills developed in an IBL classroom.

2. Curricular "Depth over Breadth"

The IBL approach requires significantly more time than traditional lecturing. Policymakers should revise national curricula to reduce the sheer volume of topics covered, allowing teachers the "chronological space" to pursue deep, inquiry-based exploration of core foundational concepts like force, energy, and momentum.

5.3.3 Recommendations for Future Research

- Longitudinal Impact: Research is needed to determine if the conceptual gains from a 3-week IBL intervention persist over a 12-month period.
- Teacher Variables: Future studies should investigate how a teacher's years of experience or subject-matter confidence influences the success of an IBL implementation.
- Socioeconomic Scalability: This study should be replicated in under-resourced rural schools to see if the lack of high-end lab equipment significantly hinders the IBL effect or if low-cost "kitchen science" inquiry can achieve similar gains.

5.4 Final Reflection

This study has demonstrated that the physics classroom need not be a place of passive reception. By embracing Inquiry-Based Learning, we treat students as what they are: naturally curious investigators. The transition from "learning about science" to "doing science" is the key to unlocking both conceptual mastery and a lifelong passion for the discipline.

While the journey toward IBL implementation is fraught with systemic challenges—ranging from teacher fatigue to rigid testing schedules—the evidence is clear: when students are given the agency to fix their own ideas, the learning is deeper, the confidence is higher, and the science is more real. It is the hope of this researcher that these findings contribute to a paradigm shift in how we prepare the next generation of scientific thinkers.

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APPENDICES

APPENDIX 1: Questionnaire for students

Dissertation Questionnaire: Enquiry-Based Learning in Physics

Research Title: The Effect of Enquiry-Based Learning on Student's Conceptual Understanding of Newtonian Mechanics in Secondary Schools.

Section 1: Student Demographics

Level: O Level Form 3

Gender: ☐ Male ☐ Female ☐ Prefer not to say

Current Physics Grade (Approximate): _____

Interest in Physics: (Scale 1-5, where 1 is "Very Low" and 5 is "Very High")

Section 2: Experience with Enquiry-Based Learning

Please tick the box that best describes your experience in your recent Mechanics lessons.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
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My teacher encourages us to ask our own questions before starting an experiment.

☐ ☐ ☐ ☐ ☐

We often design our own procedures to test a physical law.

☐ ☐ ☐ ☐ ☐

I spend more time analyzing data than listening to lectures.

☐ ☐ ☐ ☐ ☐

We use hands-on equipment to solve "What if?" scenarios.

☐ ☐ ☐ ☐ ☐

The teacher acts more as a guide than a source of all answers.

☐ ☐ ☐ ☐ ☐

Section 3: Conceptual Understanding of Mechanics

This section assesses how EBL has influenced your grasp of core Newtonian concepts.

When I study Newton's First Law (Inertia), I find it easier to understand when;

☐ I read the definition in a textbook.

☐ I observe an object in motion during a lab and try to explain why it doesn't stop.

Inquiry-based labs helped me realize that an object with zero net force can still be moving.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

How confident do you feel explaining the relationship $F=ma$ to a peer?

☐ Not confident at all

☐ Somewhat confident

☐ Very confident

When performing an inquiry task on Action-Reaction (Third Law), I discovered things I didn't expect.

☐ Yes (Please specify): _____

☐ No

Which method helps you remember mechanics concepts longer?

☐ Memorizing formulas

☐ Investigating a problem through trial and error

Section 4: Open-Ended Feedback

What was the most challenging part of learning Mechanics through an enquiry-based approach? (e.g., not knowing the "right" answer immediately, setting up the equipment, etc.)

Do you feel that "discovering" a law of physics yourself makes you more interested in the subject? Why or why not?

APPENDIX 2: Participant Information & Consent Form

Research Project Title: The Effect of Enquiry-Based Learning on Student's Conceptual Understanding of Newtonian Mechanics in Secondary Schools.

Researcher: Phoebe Muhomba

Institution: Bindura University of Science Education

1. Introduction

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully.

2. Purpose of the study

The aim of this research is to investigate how enquiry based learning (EBL) a method where students learn through investigation and problem-solving how well secondary students understand the laws of motion and force (Newtonian Mechanics).

3. What will happen if I take part?

If you agree to participate, you will be asked to:

Complete a questionnaire regarding your learning experiences in Physics.

Complete a brief conceptual test on Newton's Laws (approx. 15–20 minutes).

Possibly participate in a short focus group interview about your experience with hands-on experiments.

4. Voluntary Participation & Withdrawal

Your participation is entirely voluntary. You do not have to take part if you do not want to. Even if you say yes now, you can change your mind at any time and withdraw from the study without giving a reason and without any penalty to your grades or school standing.

5. Confidentiality & Data Protection

All information collected about you during the course of the research will be kept strictly confidential.

Your name will be replaced with a pseudonym or a code.

Data will be stored on a password-protected drive.

The results will be used for a dissertation and possibly academic publications, but you will not be identifiable.

6. Consent Statements

Please initial each box if you agree:

Statement	Initial
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I confirm that I have read and understood the information provided for the above study.	[]
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I understand that my participation is voluntary and that I am free to withdraw at any time.	[]
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I understand that my data will be anonymized and stored securely.	[]
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I agree to take part in the above research study.	[]
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7. Signatures

Student Name: _____

Student Signature: _____ Date: _____

Parent/Guardian Name (if under 18): _____

Parent/Guardian Signature: _____ Date: _____

Researcher Name: _____

Researcher Signature: _____ Date: _____

