UNIVERSITY OF EDUCATION, WINNEBA

INVESTIGATING THE EFFECTS OF INQUIRY-BASED LEARNING ON STUDENTS' PERFORMANCE IN CIRCULATORY SYSTEM AT WINNEBA SENIOR HIGH SCHOOL

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A thesis submitted to the School of Graduate Studies in partial fulfilment of the requirements for the Award of the Degree of Master of Philosophy (Science Education)

DEPARTMENT OF SCIENCE EDUCATION
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DECLARATION

STUDENT'S DECLARATION

I, EMMANUEL KWAKU BONNEY declare that this thesis, with the exception of quotations and references contained in published works which have been identified and duly acknowledged, is entirely my original work, and that no part of it has been presented for another degree in this university or elsewhere.

SIGNATURE: ……………………..……..……..……

DATE: ………………………………………..………

SUPERVISORS' DECLARATION

I hereby declare that the preparation and presentation of this thesis was supervised by the guidelines on supervision of thesis laid down by the University of Education, Winneba.

SUPERVISOR: PROF. CHARLES KWESI KOOMSON

SIGNATURE: ……………………..…..…………

DATE: ……………………………………………

DEDICATION

I dedicate this work to my late brother and coach, Mr. Thomas Sekum Kweku Bonney for his unflinching support since the very day I began my academic journey and my lovely mother, Aba Nyarko Sekum whose immerse contributions, advice and support have made me reach this far.

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ABSTRACT

The research aimed to analyze the effect of IBL on student academic performance as well as gender differences and student perceptions in the circulatory system. The study employed a quasi-experimental design with non-equivalent control groups, which was based on constructivist learning theory from Piaget (1952) and Vygotsky (1978). The study sample consisted of 60 Form 2 Home Economics students who were separated into an experimental group that learned through IBL and a control group that experienced traditional teaching methods. The study used pre-tests together with post-tests and student perception questionnaires as data collection tools, which were analyzed through descriptive statistics and inferential statistics. The findings demonstrated that IBL students achieved statistically better academic outcomes since their average test results rose from 65.1 to 80.2, while control group students showed an increase from 64.5 to 70.3. The study revealed no meaningful gender gap in academic results, which means IBL works equally well for male and female learners. The results from the post-test evaluation demonstrated that students who learned through IBL achieved higher results when compared to those who learned through traditional teaching methods according to the independent samples t-test which produced $t(58) = 4.35$, $p < 0.001$. The majority of students who experienced IBL instruction reported positive feedback because it improved their engagement levels and critical thinking abilities and made biology lessons more enjoyable. The study established that IBL functions as an efficient pedagogical method that boosts students' understanding of biology concepts together with their academic results and biological study motivation. Though further research is required to investigate the long-term impact of IBL, various educational settings and educators are advised to implement IBL methods in biology lessons while providing educational resources and teacher training to achieve successful adoption of this approach.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter focuses with the introduction to the study. The background to the study, statement of the problem and purpose of the study are discussed in the chapter. The chapter also includes the research questions that guided the study. It further discusses the significance, limitations and delimitations of the study and how the entire study was organized

1.1 Background to the Study

Inquiry-Based Learning (IBL) technique is an excellent method with significant effects on how students learn various subjects, including Biology. The learning approach follows the constructivism philosophy or theory, which emphasizes that learners develop knowledge through their efforts, not by just listening passively (Ignacio & Paras, 2024). It differs from the traditional methods where the teacher provides information, the learners memorize the concepts, and later do examinations as directed.

In the field of biology, the IBL is especially significant because biology is dynamic and complex. With the help of IBL educators can help students to learn more about biology's phenomena. One of the principles of IBL is scaffolding and according to Denmark and Yáñez-Monje (2024), educators provide students with the proper support to help them achieve better in their inquiry and gradually help them develop their inquiry skills. Scaffolding could entail issuing students with structured inquiry assignments, guiding questions, and information sources to assist them in learning and understanding biological concepts (Peuel et. al., 2022). Open inquiry helps students to develop critical thinking abilities by allowing them to evaluate findings, analyze data, and create evidence-based arguments (Sam, 2024). In biology classrooms, students may conduct investigations like analyzing scientific data, reading scientific papers, and joining information together to explain biological occurrences (Osei-Himah, & Adu-Gyamfi 2022).

The ongoing problem in science education development consists of student gender-based differences which affect their academic achievements and their science learning experiences and their interest in biology and related scientific fields. Scientists together with policymakers have studied female involvement and academic success in scientific fields as indicated by Kadir (2024). Research studies show that students' science learning attitudes and behaviours and academic performance depend on their gender because males and females show different patterns of scientific interest and confidence and achievement levels (Ochwada, 2024). Research studies fail to establish consistent patterns about how male and female students learn science differently. According to Nketsia (2024), male and female students differ significantly in their cognitive, affective, and psychomotor achievement, particularly in science-related tasks that require abstract reasoning and problem-solving skills Research studies have shown that students achieve the same results regardless of their gender when teachers use proper teaching methods (Sicard et. al., 2022). Research results show that science achievement inequalities between genders stem from more than natural biological differences and social influences because they also depend on how teachers present their material in classroom settings. Given the discussion about gender-based performance differences together with the rising focus on student-centered teaching methods, it is vital to examine how IBL affects male and female students' performance during biology lessons.

Harlen (2015) has also highlighted the importance of IBL in helping the students to develop a sense of ownership and therefore take charge of their own learning and hence pursue their own interests. IBL can enable the students in biology lessons to undertake private initiatives such as a research project, design and execution of an experiment, or even an investigation into the relationships between biology and other disciplines such as environmental science and biotechnology (Simonsen et al., 2022). It is to be noted that the advantages of IBL are not only restricted to the learning achievement of the students but also extend to their affective outcomes such as aspirations, inspiration, and self-confidence (Kumar & Johnson, 2018). Participation of the students in the scientific process can stimulate their interest and curiosity in biology and therefore make them to take up the subject for the rest of their lives (Riga, 2020). However, implementing IBL in biology classrooms requires careful consideration of various factors, including instructor education, course preparation, and resources availability (NSTA, 2000). Teachers may require preparation to improve their comprehension of inquiry-based education and create methods for effectively implementing them into their educational practices (Windschitl et al., 2008).

1.2 Statement of the Problem

Teaching biology as a subject at Winneba Senior High School faces substantial challenges which reflect in students' poor academic performance, lack of engagement during lessons, and persistent reliance on traditional teaching methods. Despite the subject's popularity among students, many struggle to grasp and master fundamental concepts in biology, which affects their ability to progress successfully to more advanced topics.

As noted by the Cooper & Adams (2022), biology, as a subject, presents unique challenges due to its broad scope, ranging from molecular biology to environmental science. These complexities demand specialized teaching approaches that are often not addressed in traditional classrooms. The lack of effective teaching strategies, coupled with resource constraints and insufficient teacher training, intensifies these challenges. Students are left without the critical thinking skills and conceptual understanding necessary for academic success, which hinders the nation's broader educational and technological advancement goals.

To address these challenges, the researcher proposed the adoption of inquiry-based learning (IBL) methods to transform biology education at Winneba Senior High School. This was to improve student engagement, and raise academic performance to meet national educational standards. Dian (2024) asserts that IBL represents a student-centered approach that emphasizes active learning through questioning, exploration, experimentation, and analysis. This approach aligns with the active and exploratory nature of scientific learning and offers a pathway to overcome the limitations of traditional lecture-based methods. According to Aghazadeh (2021), the emergence of Inquiry-Based Learning (IBL) has sparked considerable interest in education due to its potential to transform the learning experience and enhance student outcomes. However, despite the growing interest for IBL, there exists a notable gap in empirical research concerning its effect on students' performance in biology education. While numerous studies have explored the effectiveness of IBL across various disciplines, including mathematics, physics, and chemistry, there remains a paucity of research specifically examining its effects within the context of biology classrooms (Dian, 2024). For that reason, the study seeks to examine the effects of IBL on students' performance in circulatory system at Winneba Senior High School.

1.3 Purpose of the Study

The purpose of this study is to examine the effects of implementing Inquiry-Based Learning (IBL) strategies on students' academic performance in circulatory system.

1.4 Research Objectives

The primary objectives of the study are as follows:

1. Assess the effects of inquiry-based teaching approaches on students 'performance in biology.
2. To analyze the effects of IBL on male and female students' academic performance in biology.
3. Explore students' perceptions towards IBL in learning biology.

1.5 Research Questions

The study seeks to find answers to the following questions:

1. What is the effect of inquiry-based teaching approach on students' performance in biology?
2. What is the effect of IBL on male and female students' academic performance in biology?
3. How do students perceive the use of IBL in learning biology?

1.6 Null Hypotheses (H0)

1. There is no statistically significant difference in the academic performance of students before and after the introduction inquiry-based teaching approach
2. There is no statistically significant difference in academic performance between male and female students in biology under the influence of Inquiry-Based Learning (IBL).

1.7 Significance of the Study

The significance of this study is stated in the following reasons

- The study will help to gather suitable teaching and learning techniques to curb poor performance of students in biology as expected.
- Moreover, by demonstrating the effectiveness of IBL in enhancing students' academic achievement, educators can incorporate inquiry-based approaches into their teaching strategies. This can lead to the design of more engaging and effective learning experiences that cater to diverse student needs and learning styles.
- Also, it is anticipated that, both Male and female students will have equal opportunity to benefit from the use of IBL to correct challenges in some concepts in biology

1.8 Delimitations

The study focused on Form Two students from Winneba Senior High School who received instruction on circulatory system through the Inquiry-Based Learning method. The research study focused on a single experimental group together with a single control group because of limited time availability and the existing structure of the school. The research study involved only students who studied Biology at

Winneba Senior High School which means the results do not apply to students who study other subjects or attend different educational institutions.

1.9 Limitations

The study used a quasi-experimental design which prevented random participant distribution because it included groups that did not receive random group selection thus selection bias might have entered the research. The study used pre-test results to measure initial group differences yet it failed to establish complete equality between the groups.

The treatment period stayed brief which prevented researcher from studying how students' Inquiry-Based Learning performance would change across time. The achievement test results showed two major factors which affected student performance because some students developed test anxiety and at the same time day students failed to show up for their scheduled classes. The research team established proper methods to reduce the impact of these limitations which helped them maintain research value

1.10 Operational Terminology

1. **Inquiry-Based Learning (IBL)**: An educational approach that emphasizes active exploration, investigation, and discovery by students, guided by questions, problems, or phenomena. In this study, IBL involves students engaging in hands-on experimentation, data analysis, and critical thinking to deepen their understanding of selected topics in biology.
2. **Performance**: The measurable outcomes or achievements of students in biology education, including academic achievement, conceptual

understanding, and attitudes towards learning biology. Performance may be assessed through standardized tests, grades, surveys, or other measures.

3. **Selected Topics in Biology**: Specific areas or concepts within the field of biology chosen for investigation in the study. Examples of selected topics may include cellular biology, genetics, ecology, and evolution. These topics are relevant to the biology curriculum and suitable for inquiry-based instruction.
4. **Experimental Group**: The group of students who receive instruction using an Inquiry-Based Learning approach. In this study, the experimental group comprises students assigned to form 2 Home Economics 1, where IBL strategies will be implemented in teaching selected topics in biology.
5. **Control Group**: The group of students who receive instruction through traditional teaching methods. In this study, the control group comprises students assigned to form 2 Home Economics 2, where traditional instructional approaches will be employed in teaching the same selected topics in biology.
6. **Academic Achievement**: The level of mastery or proficiency demonstrated by students in understanding and applying biological concepts and principles. Academic achievement may be assessed through tests, quizzes, assignments, or other performance-based assessments.
7. **Attitudes towards** Learning Biology: Students' beliefs, perceptions, and feelings about the study of biology and their learning experiences in the subject. Attitudes towards learning biology may be assessed through surveys, questionnaires, interviews, or observations.
8. **Purposive Sampling**: A non-random sampling technique used to select participants based on specific criteria relevant to the study objectives. In this

study, purposive sampling will be used to select students for the experimental and control groups based on their academic abilities and characteristics

1.11 Organization of the Study

The study is organized into five chapters. Chapter One, outlines the research problem, objectives, and significance of the study. It also formulates research questions and adopts a theoretical framework based on constructivist learning theory, providing a clear direction for the research. Chapter Two, the literature review, delves into relevant studies on IBL in biology education. This comprehensive review helps establish the study's context and highlights existing knowledge in the field. Chapter three presents the methodology describing the research design, participant selection process, and data collection methods. These methods include pre- and post-instructional assessments, surveys, and observations. By detailing these aspects, the chapter ensures transparency and credibility in the research process. Chapter Four presents' findings, incorporating both quantitative and qualitative data. This chapter comprehensively analyses the results, giving a holistic view of the research outcomes. Chapter Five interprets the results and explores their implications. As the final chapter, the conclusion summarizes the key points, emphasizing the study's contributions and importance.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

The aim of this chapter is to review the available literature regarding the Inquiry-based learning (IBL) and its effects on the students' performance in Biology. Through this, an understanding concerning the theoretical background of Inquiry-based learning in general, biology education and empirical evidences concerning its impact on students' performance will be provided. Moreover, this section identifies gaps in literature and provides justification for the present study.

2.1 Theoretical Foundations of Inquiry-Based Learning

Inquiry-Based Learning (IBL) is based on the learning theories of constructivism that suggests that learners construct knowledge as they engage in the learning process. This section explores the following: constructivism, scaffolding, and the role of inquiry in developing critical thinking and problem-solving.

2.1.1 Constructivist theory of learning by Vygotsky (1978) and Piaget (1952)

Constructivist theory asserts that students should construct their knowledge and share their knowledge views with the society and that they should be active participants in their learning process. Waite-Stupiansky (2022). In his cognitive theory, Piaget (1952) opines that children go through distinct stages in cognitive development that are qualitatively different in terms of the way the children think or understand (Golzar, 2022). He therefore argues that children should actively be involved in the learning process, doing things that challenge and captivate the children's thinking so that new ways of understanding new knowledge are built. To Piaget, learning is an active process where the children actively assimilate aspects of the physical world into their cognitive structures and accommodate them. Contrasting Vygotsky (1978), he was firm on the importance of social interactions in the process of learning. His ZPD (Zone of Proximal Development) is a notion that explains the tasks that a learner cannot complete on their own but can with a learned peer, parent, or teacher (Vygotsky, 1978). Consequently, upon completion of the given task, a learner develops a cognitive capacity that is higher than one with no guidance. Additionally, he uses the term scaffolding to refer to a technique that all instructors should use to teach learners their ZDP (Zone of Proximal Development) (Puntambekar, 2022). In a study conducted by Dian (2024), it was stated that, in the context of Inquiry-Based Learning (IBL), constructivist theory is operationalized by placing students at the center of the learning process. Therefore, instead of being passive recipients of information during teaching and learning, students actively participate in exploring concepts, designing investigations, conducting investigations, and drawing conclusions based on their findings (Lee, 2014). This active involvement is crucial for enhancing students' understanding and encouraging ownership of their education, and Sam (2024) has pointed out that inquiry-based learning based on constructivist principles can drastically improve students' understanding of concepts and critical thinking. For example, a study done by Athuman (2017) showed that students that were subjected to inquiry-based science instruction showed a better understanding of scientific concepts and processes than those that were taught using traditional methods.

Similarly, Bruder and Prescott (2013) reported that IBL promotes the development of problem-solving and the ability to apply knowledge to new situations. Furthermore, the social constructivist aspect of IBL is seen in collaborative learning spaces where students learn together, solve problems, share ideas, and build on each other's understanding. This collaborative environment aligns with Vygotsky's emphasis on the societal impact on cognitive development. For example, Black et al. (2018) found that students that engaged in group projects and discussions during inquiry-based activities were seen to have better understanding and retention of science concepts. This approach helps students navigate complex biological topics and develop the skills necessary for independent inquiry.

According to the constructivist theory, as brought forward by Piaget and Vygotsky, we can completely understand the way students learn through active engagement and social interaction. Inquiry-based learning, which is rooted in constructivist principles, is a student-led learning approach that enhances a deeper understanding of concepts (Khan, 2023). Empirical evidence highlights the effectiveness of constructivist-based practice in the classroom, especially when teaching science and biology.

Figure 1 is the theoretical explanation of IBL learning.

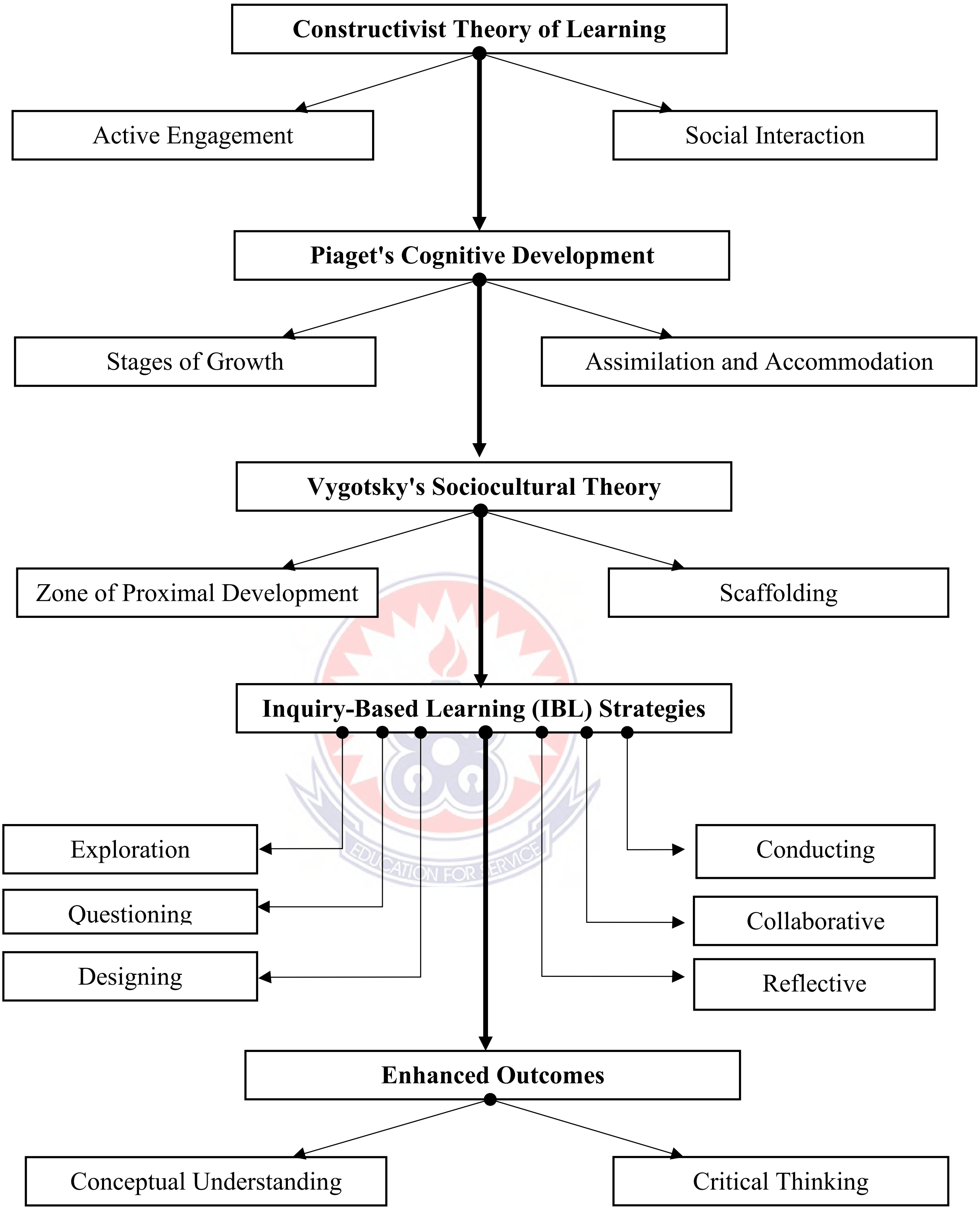

Figure 1: The Theoretical Framework
Source: *(Piaget, 1952; Vygotsky, 1978*).

2.1.2 Scaffolding in inquiry-based learning

Scaffolding is a vital part of the Inquiry-Based Learning (IBL), and it is necessary for the development of inquiry skills of students. The concept of scaffolding according to Belland (2014) is a support provided by a teacher/parent, peer, or a computer- or a paper-based tool that allows students to meaningfully participate in and gain skill at a task that they would be unable to complete unaided. As students gain proficiency, this support is gradually reduced to enable them to assume greater responsibility for their education. Access to resources, planned tasks, and guided questions are some of the tactics that make up effective scaffolding in IBL (Reijerkerk, 2020). These techniques are crucial for encouraging self-directed inquiry and a more thorough comprehension of the topic. Petersen (2022) highlights that scaffolding can take many forms, such as providing background information, modeling scientific inquiry processes, or offering feedback and encouragement throughout the learning process.

2.1.2.1 Guiding questions

Guiding questions are questions that are provided to guide the mind to think more critically about a subject matter. They help students to determine what to focus on. This means that they should be in a position of making the students to have critical thinking. For example, in a biology class, when investigating enzyme activity, it is viable to investigate questions such as; how do different environmental factors affect the enzyme activity? How does enzyme structure relate to its function? These questions will help the students comprehend and learn more about biology (Hmelo-Silver et al., 2007).

2.1.2.2 Structured tasks

Structured exercises set a clear path for students to follow as they conduct their investigations. They are aimed at breaking down complex activities into simpler steps so that students can acquire skill upon skill. For example, a structured task in the biology class can be that of formulating a question about a given observation, then formulating a hypothesis about the question, proceeding to design an experiment, then collecting data, analyzing the data, and, finally, making conclusions. These steps provide a clear framework to students through which they can conduct their investigations and eventually master the subject (Puntambekar & Hübscher, 2005).

Access to resources is another crucial aspect of scaffolding in IBL. Resources which include textbooks, scientific journals, online databases, laboratory equipment, and multimedia tools.

Instructional materials serve as fundamental tools for improving educational results. According to Alam (3023), these materials stimulate student participation while providing personalized learning approaches to various student needs and making abstract ideas understandable with concrete examples. Through proper implementation, these resources connect theoretical knowledge with practical applications to help students achieve better comprehension of real-life concepts Machado (2023).

Gradual Release of Responsibility An essential characteristic of scaffolding is the slow transfer of responsibilities from the teacher to the student. Initially, teachers offer a high level of support by giving direct instruction and close supervision. As students become more confident and proficient, the level of support is slowly lessened to encourage the students to become more responsible for their learning. This way, students are able to gain the knowledge and confidence to perform independent inquiries and think critically about the topic (Palincsar, 1998).

Empirical research proves that scaffolding improves students' outcomes in Inquiry-based learning (IBL). Teaching students with scaffolding propels them forward. Students engage well in scientific research according to Tabak and Kyza (2018). Students also get to understand better what they are being taught. Teachers can better manage many students with the help of scaffolding as written by Kim, (2017). Teachers will also help students get to think more broadly and deeply about the content. Scaffolding tasks in IBL will demand a great deal of teacher planning and preparation. Teachers must know their students very well. Teachers should know what they need to learn and be able to monitor their own work. Teachers should also respond well to students' needs and support and be able to adjust to their tasks, their immediate objectives, and their long-term objectives. Effective scaffolding not only facilitates students' immediate learning but also prepares them for future independent inquiry, fostering a lifelong interest in science and critical thinking skills (Bell et al., 2005).

Scaffolding is a vital component of Inquiry-Based Learning, providing the necessary support to help students develop their inquiry skills gradually. Scaffolding through guiding questions, structured tasks, and access to resources supports independent exploration and learning of scientific concepts. As responsibilities are gradually reduced, pupils can improve their ability to think critically and solve problems. According to empirical data, scaffolding is essential for achieving successful IBL and plays a part in encouraging higher-order cognitive abilities and more in-depth interaction with the material (Aghazadeh, 2021).

2.1.3 The role of IBL in promoting critical thinking and problem-solving

Inquiry-Based Learning (IBL) is a robust pedagogical method that fosters the sense of critical thinking and problem-solving skills by encouraging students to be involved in higher-order thinking activities (McNeill et al., 2006).

One of the central components of IBL is the analysis of data. This process involves examining data collected in experiments and forming reasoned judgments based on that data. This means that students must be able to choose between relevant and irrelevant data and recognize possible sources of bias. It also means that they must understand the quality and reliability of the sources for this data. Kuhn (2015) points out that the ability to evaluate information is a necessary part of scientific literacy and a healthy skepticism toward unsupported claims.

Constructing the evidence-based explanations by students will have them synthesize the information in different resources and come up with a coherent, scientifically sound argument. By students practicing this, it helps them in problem-solving, for they have to identify problems, generate a hypothesis, test them by conducting an experiment, and come to a conclusion through asking certain questions in regard to the experiment. Sampson and Clark (2009) elaborated that the students' constructing evidence-based explanations will have them understand the scientific principles and come up with an effective way to portray their idea.

This method lets you come up with a creative answer to a complex question or situation. Active thinking fosters the ability to question assumptions, evaluate arguments, and consider alternative viewpoints. According to Facione (2011), the approach is important in this age as people are bombarded with data from diverse sources. With the help of IBL, you can develop critical thinking skills to solve complex problems.

Problem-solving is another skill developed through inquiry-based learning. Learners often come face-to-face with real-world problems that need them to think outside the box. Through IBL, the students gain the ability to tackle these problems step by step, breaking them down and forming strategies to solve them. IBL prepares students to be proactive learners who are capable of adapting to new information and changing circumstances. This can be attributed to the fact that, as noted by Bransford, Brown, and Cocking (2000), the ability to learn independently and continuously is crucial in a constantly changing world where knowledge and technology are continuously evolving.

Empirical studies support the fact that IBL programs can increase students' critical thinking and problem-solving abilities. A meta-analysis conducted by Lazonder and Harmsen (2016) implies that students who underwent IBL appeared to have significantly improved their critical thinking and problem-solving skills compared to their peers who participated in traditional training. Live videos are shown to be more effective than pre-recorded videos in situations in which a person is required to rely exclusively on his/her listening ability. Also, a study by Geier et al. (2008) shows that students taught with IBL performed better than students in traditional schools in terms of their scientific inquiry and achievement in standardized tests. IBL can improve students' critical thinking and problem-solving skills because it requires students to think of answers to questions, to evaluate evidence, and to explain what they know about a topic. These skills are important for students to develop to keep up with the ever-changing world, to become successful, and to learn how to understand what is going on around them. Research on this topic has given a lot of information about the effects of IBL on education; students and teachers can relate to the findings, and the research does not raise any questions about its credibility.

2.2 Inquiry-based Learning (IBL) Strategies in the Classroom

Inquiry-Based Learning (IBL) is a technique that places students in control of their learning experience. Here, students are encouraged to ask, explore, and comprehend the subject matter. The regular teaching techniques in the schools do not give the students an opportunity to be in charge. This is because teachers pass on information to the learners, and they receive the information in a passive manner. Through this approach, the students' learning experience is improved. The implementation of IBL strategies in the classroom has shown significant promise in boosting students' knowledge, engagement, and critical thinking skills, particularly in science education.

One fundamental strategy involved in IBL is the formulation of hypotheses. It aims at enabling the students to reason and make an educated guess. In accordance with Bell, Smetana, and Binns (2005), encouraging students to come up with their hypotheses helps the students to gain ownership of their learning and thereby understand the science processes. From this strategy, the students then learn to develop questions that can be tested. This is intended to make the learning more active and more inquiry-based.

Designing and performing investigations are major central processes of IBL. This is a teaching approach that involves learners in planning and conducting analysis to test presuppositions. Krajcik et al. (2014) explained that when designing investigations, learners do not only learn the scientific method but also gain valuable skills like problem-solving, data gathering, and analytical thinking. These skills will help students understand better what they are studying. After an experiment has been conducted, analyzing and interpreting data follows in IBL. This involves the students looking at the data they have and drawing a conclusion from it. McNeill et. al. (2006) established that students who carried out data analysis acquired better critical thinking skills as well as a more in-depth understanding of scientific concepts. This means that the exercise not only reinforces the ideas learned in class but also educates the students on how to apply the concepts they have learned in various circumstances.

Reflection is an essential part of the IBL process. Reflecting on the findings involves students thinking about what they have found out in experiments and how they can relate it to real-world situations. According to Hmelo-Silver et. al. (2007), reflection can help students consolidate their learning and relate new things to what they already know. This method encourages students to also think about their findings and how scientific knowledge can be used to solve real-life problems.

IBL additionally cultures collaborative learning, and it allows for pupils to engage in groups in order to discover answers to questions and issues. Alzubi et al. (2022) discovered that teamwork in a classroom develops a connection and enhances learning by allowing students to share different viewpoints and suggestions. Working in teams helps students to develop their communication and teamwork abilities, which are required for studying science and other topics.

Technology incorporation in IBL is another strategy. This can take the form of simulations, modelling software, and data analysis programs that could be used to make the inquiry more insightful. According to Quintana et al. (2018), technology is an excellent scaffold and can guide students through their inquiries as well as give them immediate feedback.

2.3 Application of Inquiry-Based Learning in Biology Education

Biology as a discipline benefit highly from inquiry-based learning because biological systems are pretty vast and complicated. It encourages students to get their hands dirty and make discoveries, which is far different, and more effective, than the kind of learning that takes place during a normal class.

IBL in biology puts a strong emphasis on scientific inquiry that mimics real research procedures. Students are urged to have a hands-on, investigative approach by generating questions, planning experiments, collecting data, and analyzing the results. Such as it was discovered that students grasped biology better by undertaking gene sequencing and DNA extractions (Ederson & Aliazas, 2024). Correspondingly, fieldwork and biodiversity evaluations contribute to the understanding of ecosystem dynamics (Manishimwe et al., 2023). IBL boosts student engagement and retention of information, according to a study. According to Aliazas (2024), biology students who studied via IBL got more engaged and showed high-level thinking skills. Students in IBL biology classes got more engaged and showed high-level thinking skills, according to Aliazas (2024). In order to prepare students for future academic and professional challenges, Delfino et al. (2024) observed that IBL promotes inquiry skills and stimulates conceptual change.

According to NGSS Lead States (2013, p. X), inquiry-based science education is significant because it helps the students to understand the methods involved in science. Louis and Hokayem (2023) went on to point out that undergraduate scholars in inquiry-taught science programs demonstrated a much better understanding of the nature of science compared to those in regular lecture courses. This section will talk about how the application of IBL to the teaching of various biological concepts can be beneficial for students.

2.3.1 Enhancing understanding of biological concepts

Inquiry-Based Learning (IBL) is an interesting way to teach biology, and it helps students to understand the concept of biology better. Many students find it difficult to understand subjects like biology, cell processes, genetics, and ecology using the traditional method of teaching.

Learning about cells is crucial in biology, though many times it is difficult for students to understand. Inquiry-based learning helps students understand cells by showing how the cells function. For example, when learning about enzymes, students can test the rate of enzyme action under different conditions and temperatures. These practical experiments allow learners to see how factors such as temperature, pH, and substrate concentration affect the rate of enzyme action, which helps them understand better (Bell et al., 2005). An experiment by Sesen and Tarhan (2013) established that students were better able to grasp the concepts of cell respiration and photosynthesis after they participated in a lab experiment. Through the manipulation of variables, they were able to obtain a concise picture of these simple cellular activities.

Genetics is one area that is extensively handled by IBL. Teachers mostly use the repetition method in teaching genetics, which can be very boring and not effective. IBL has the students discover for themselves what happens using various techniques. The students, for instance, can accomplish genetic crosses with some organisms like plants, fruit flies, etc. It can also involve the study of pedigrees and other means of studying inheritance through computer simulations and analysis of data. Davenport et al. (2015) indicated that students who engaged in inquiry-based genetics experiments such as breeding, DNA extraction, and gel electrophoresis had a deeper understanding of Mendelian and non-Mendelian genetics than those who had not engaged in such inquiry-based work. Such laboratory activities create the connection between the theoretical and practical facets of the subject and enhance student motivation. This applies to the field of ecology. IBL in ecology is often done outside in natural environments in order for students to observe the relationships in nature. For example, this can involve measuring how many different types of bugs and lengths are in different types of trees, looking at the food chain and how different levels are connected, or seeing how changes made to the water of a pond will be reflected in the pond. Hogan and Corey's (2018) study showed that students had a better understanding of ecological science principles and a better ability to analyze data after completing their inquiry-based projects. The empirical work and projects helped them understand more about real-life science and think critically about ecological scientific topics.

There are various successful attempts at implementing IBL in biology classes that have been shown to lead to more comprehensive understanding of biological concepts. The BioKIDS curriculum is one such successful implementation, which has middle school learners focusing on ecosystems and relationships between organisms. The students are required to come up with observations and are involved in data collection about the ecosystem in question. Another example of a project-based learning activity for high school students is Genetics Project-Based Learning (PBL), where students will have a chance to learn about genetic disorders by conducting research and finally presenting their work. This not only helps students to learn genetics but also improves their research and presentation skills (Sandoval & Reiser, 2004).

The Cell Biology Education Consortium (CBEC) also offers resources and assistance for integrating inquiry-based activities into cell biology classes. By involving students in experiments like measuring cell respiration, observing mitosis, and examining cell signaling pathways, CBEC fosters a deeper comprehension of cellular processes (Lopatto, 2009). Figure 1 illustrates the conceptual understanding of IBM.

2.3.2 Developing scientific skills

Inquiry-Based Learning (IBL) is very influential in developing crucial scientific skills in students since skills such as hypothesis formulation, experimentation, data collection, and data interpretation are essential for a good scientific understanding, as well as for independent research, which contributes to a deep appreciation of science and scientific approaches (Krajcik et al., 2014).

The process of hypothesis is important in research since it leads to the formulation of workable ideas. IBL would effectively encourage students to perform hypothesis testing. It is very essential in training that would help students in arriving at a plausible working hypothesis that they would use in conducting their research. The study by Herron (2009) was aimed at finding out whether IBL could be used to develop hypothesis skills. To this effect, it was discovered that there was a significant difference in the number of students who could develop a research question as well as in the number that could conduct an investigation between students who used IBL and those who did not.

Experimentation style is another key aspect of IBL, as it helps learners learn how to design an experiment to test their hypothesis. It offers opportunities for students to plan their inquests, choose the variables to be changed, and determine the checks that must be included to get valid results. This practical experience is to help them learn the complications of scientific experimentation.

According to Windschitl, Thompson, and Braaten (2008), students who are actively engaged in scientific inquiry demonstrate more advanced skills in conducting valid and reliable scientific experiments. Accurate and systematic capturing of data is very important for reliable scientific research. IBL imparts to the students the need for accurate capturing and recording of data. By conducting experiments and capturing data, students understand the importance of accuracy in their work. Capps and Young (2016) conducted a study that found that IBL students are better at handling scientific gadgets and their data recording skills were better. This not only hones their technical skills but also makes them appreciate the diligence involved in scientific study.

The meaning of the data analysis is the way of determining the collected information in order to add more meaning to it. IBL shows the process of data analysis, which includes the statistical data, graphical data, and interpretation of the result. The knowledge is important because it helps in the understanding and interpretation of the scientific research. Furtak and Ruiz-Primo's (2008) report shows the students who take part in the IBL activities that they develop their skills in data analysis. It has been developed in the sense that the students are able to analyze the data and draw out conclusions from it. It is important in both academia and the field of science.

Through Inquiry-Based Learning (IBL), students gain an extensive range of scientific skills required to complete independent research projects. These skills include critical thinking, problem-solving, and effective communication to others about scientific ideas. Students have to go through the whole process of scientific inquiry that includes the statement of the problem, the hypothesis, and data analysis. Skills developed through IBL are not confined to the classroom; they are highly applicable to real-world scientific challenges and independent research projects. For example, students who have mastered these skills can undertake complex research projects, such as studying environmental impacts, investigating biomedical phenomena, and exploring new technologies. According to the study by Crawford (2014), students who have engaged in IBL had more successful independent research projects that showed more creativity; they were conducted in a more rigorous manner, and the students have demonstrated more perseverance.

According to a study by Crawford (2014), students with IBL experience were more effective in their own research activities, exhibiting better inventiveness, methodological rigor, and tenacity. Additionally, the abilities learned via IBL provide the groundwork for a lifetime of scientific investigation. In order to prepare students for future jobs in science, technology, engineering, and mathematics (STEM), IBL cultivates a thorough awareness of the scientific method as well as the capacity for independent study. Additionally, it fosters a curiosity-based learning style that transcends traditional schooling.

2.3.3 Fostering motivation and engagement

Research has constantly shown that Inquiry-Based Learning (IBL) can boost the motivation, engagement, and self-efficacy of students towards learning biology. This involves actively engaging students in the scientific process such that they feel like owners of the question and this makes them very curious learning more on the content (Kumar & Johnson, 2018).

Motivation is a significant factor in the success of education with particular reference to science education. IBL guarantees intrinsic motivation as the children are involved in experiments that they find exciting and can discover on their own. According to Self-Determination Theory by Ryan and Deci (2024), children get the drive to engage in activities when they feel that they are free, competent and that they are connected to others. Under IBL, students have the freedom to select topics they want to research, perform experiments, and make conclusions. The autonomy makes them motivated (Deci & Ryan, 2024). A study by Aidoo et al. (2024) revealed that students under the inquiry-based learning program were more motivated intrinsically than those in other classes. They found it enjoyable and significant as they were dealing with real problems. This is supported by additional findings showing there is a likelihood that IBL increases excitement and interest in the subject matter (Kanter & Konstantopoulos, 2010).

Engagement in learning activities is another main aspect of academic success. By incorporating students in active learning processes, the IBL approach fosters both cognitive and emotional involvement (Sam, 2024). The mental work and cognitive investment needed for learning tasks, such evaluating, synthesizing, and applying new information to pre-existing understandings, is referred to as cognitive engagement.

Emotional engagement involves the feelings and beliefs students have about learning, such as their interest in biology, their enjoyment of investigations, and the degree to which they feel they belong within the field (Membiela et. al., 2023). Through participating in inquiry-based learning activities, students are more likely to be cognitively engaged as they solve problems, conduct experiments, and analyze data. This active involvement helps students to develop a deeper understanding of biological concepts and develop their critical thinking skills. Emotional engagement is fostered through working together with other students and the excitement of discovery (Riga, 2020).

Research conducted by Frezell (2018) indicated that students in IBL enjoyed a lot in class. The research showed that the students were more active in class discussions, asked questions, and they are interested in the given topic. These characteristics help the students improve academically. In addition, self-efficacy is a feature that determines the level of success to students in school. IBL helps in promoting self-efficacy in that, students are given a chance to try out the questions and as they get positive feedback, they are able to reflect on the progress (Nzoma et. al., 2023). In the process of activities involved in IBL activities and pass, the student's confidence of understanding the subject matter increases (Robinson & Aldridge, 2023). In addition, Kumar & Johnson (2018) found out that students who take part in IBL have high levels of self-efficacy in Biology. This is because, the activities involved in IBL are more practical and more of explorative which in the process help students to acquire good skills and knowledge in the field (Sam, 2024). The high level of Self-efficacy helps students to have the courage to engage their teachers in class by asking questions where they don't understand. This happens to those students who have great willingness in learning.

One of the long-term benefits of motivation, engagement, and self-efficacy fostered by IBL is continued interest and achievement in biology. When students are motivated and engaged, they are likely to keep studying the subject. Research has shown that the Inquiry-Based Learning (IBL) can improve students' motivation, engagement, and self-efficacy for learning biology as indicated by Nzoma et. al. (2023). This is mainly because the method seeks to engage students in carrying out research on their own, which makes them feel responsible for their engagement and can lead to a genuine interest in the subject (Kumar & Johnson, 2018).

Motivation plays a crucial role in education, especially in science education. Inquiry-based learning helps to develop intrinsic motivation by allowing kids to question and investigate things that interest them. Cudworth and Tymms (2024) note that motivation is the strongest when people feel a sense of relatedness (a feeling of connectedness), autonomy (a feeling of being able to make choices), and competence (a feeling of being capable). IBL cultivates the sense of autonomy as young scientists can choose the topics, form the questions, and conduct experiments, which is very likely to boost their interest in studying (Sassano, 2022).

Research by Frezell (2018) has shown that students in inquiry-based structures are more engrossed in and enthusiastic about science. The knowledge students are more likely to ask and answer questions and show more of an interest in science and what they are learning. Self-efficacy has been shown to be a key indicator of academic success and one's intent to stay in school and graduate. IBL helps build self-efficacy by providing students with opportunities to succeed, receive feedback, and reflect on their learning. As students' complete inquiry-based assignments and succeed, their belief that they can do well in science and understand the material grows (Robinson & Aldridge, 2023). In a study by Kumar and Johnson (2018), students who participated in IBL had a higher self-efficacy in biology. Their study found that through the labs and inquiry at the college level, students were able to learn basic scientific skills that helped them with understanding the information, therefore raising their self-efficacy. This self-efficacy can then help them stick with it when science gets tough and maybe even keep them in the field.

One of the long-term benefits of motivating, engaging and inducing self-efficacy in biology according to Nadile et. al. (2024) is the continuity of interest in and high achievement in biology and their study stress on the importance of motivation, induction of self-efficacy, and engagement/intensive learning in the science of biology. When students are motivated and induced with self-efficacy to learn, the continuity and completion of the course are almost certain. These are the aims of the authors in this paper. Ahmed and Shogbesan (2023) in their research on the efficacy of learning in science education showed that students who experienced instructional use of IBL in their mathematics and science classes were more likely than other students to show interest in pursuing science-oriented elective courses. This study is a replication of the work of Kanter and Konstantopoulos (2010) to investigate the effects of IBL on learning about the science of biology, and the introduction of more effective scientific inquiry and induction of learning self-efficacy in the course.

2.4 The Effects of Inquiry-Based Learning

This section reviewed empirical studies that have investigated the effect of IBL on student performance in biology and other scientific disciplines. The review focused on academic achievement, conceptual understanding, and attitudes towards learning.

2.4.1 Academic achievement

Research conducted by Reiser et. al. (2024) indicated that Inquiry-Based Learning (IBL) implementation leads to better biology academic results among students. The method helps students grasp biological concepts better while simultaneously raising their academic performance levels. In a study conducted by Hiltunen (2022) discovered that students who participated in inquiry-based assignments achieved better biological knowledge than those who used traditional educational methods.

This section will demonstrate the educational performance advantages of IBL through current academic literature documentation.

The primary outcome of Inquiry-Based Learning emerges from its capacity to help students understand biological principles at a deeper level. Students who participate in hands-on activities and guided inquiry learning can meaningfully explore complex biological topics which include genetics, cellular processes, and ecology (Nwankwo et. al., 2024). Their study combined multiple research studies to reveal that IBL students experienced significant improvements in their science concept knowledge regarding biology.

The methods of inquiry-based learning (IBL) which include hypothesis creation together with experimental activity and data analysis produce better knowledge acquisition in students compared to traditional educational approaches.

IBL practices demonstrate a positive correlation with biology test scores and academic achievements. A study of inquiry-based science programs discovered that students who used IBL approaches outperformed their peers who used conventional methods in standardized science assessments (Geier et al., 2024). The research findings demonstrated that students who participated in IBL gained fundamental analytical abilities essential for examination success. The combination of hands-on learning and independent investigation through IBL leads to enhanced material interaction which supports better knowledge retention and comprehension thus producing improved academic results.

The connection between improved student motivation and higher engagement along with academic success shows the positive influence of inquiry-based learning (IBL).

Students who actively participate in learning processes develop genuine subject matter interests. The increased student involvement at school results in better attendance percentages alongside higher levels of activity in classroom tasks and more dedication to learning. A study by Machado and Nahar (2023) showed that students who experienced inquiry-based science instruction displayed enhanced interest and involvement in science classes and this improved academic success in the subject.

IBL programs advance students' cognitive abilities beyond basic comprehension to include critical thinking along with analysis and synthesis abilities that enable success in biology education. Through the practice of student-driven questioning and experimental design and result interpretation, IBL enables students to achieve an advanced scientific comprehension of concepts and processes. Research by Wilson et. al. (2010) revealed that students who participated in inquiry-based learning demonstrated significant advancements in their capacity to think critically and problem-solving skills. These essential abilities gained from biology studies extend to multiple academic fields and practical contexts to boost student performance in all learning areas.

The existing body of research demonstrates that inquiry-based learning produces consistent positive academic results across all educational settings. Various educational studies including research from Furtak et al. (2012) showed that science achievement improved significantly across different grade levels under inquiry-based instruction. According to their research results the implementation of IBL through student-focused learning and active participation helped students develop better scientific understanding which resulted in higher academic achievements.

Alfieri et. al. (2011) conducted a meta-analysis which demonstrated that discovery-based learning approaches including IBL produced superior academic achievement results compared to traditional teaching methods. According to their research findings the provision of structured support through IBL with scaffolding and feedback played a critical role in enhancing student learning outcomes.

Research confirms that students achieve better academic results in biology classes through the implementation of Inquiry-Based Learning. Through its scientific educational method, IBL delivers a comprehensive learning model that strengthens biological understanding alongside test performance and course grades and boosts student motivation and critical thinking abilities. Empirical research demonstrates that IBL helps students succeed academically and shows promise for revolutionizing biology education and supporting life-long learning.

2.4.2 Conceptual understanding

An extensive body of research demonstrates that Inquiry-Based Learning (IBL) brings about major improvements in student conceptual understanding through the promotion of knowledge connection and real-world application. Students who receive this teaching approach gain better understanding of scientific concepts which are fundamental for their academic success and career advancement.

Teaching with IBL methods focuses on expanding student learning through their existing knowledge base. The combination of new material with existing knowledge enables students to develop more complete biological concept understandings. Research by Linn et. al., (2015) demonstrated that this method facilitates deep comprehension through student-driven connections. Students learn about ecosystems through their local environment knowledge because it enables them to understand important ecological concepts. According to Sam (2024), IBL promotes student learning through practical applications which results in better understanding of theoretical concepts. When students examine local water bodies for pollution effects in the study, they use chemical knowledge alongside biological understanding to interpret their findings on environmental health. He therefore concluded that, students find their studies meaningful through this method because it enables them to identify how their learning applies to practical life situations. Through real-world applications students see how abstract ideas directly impact their lives because they provide both context and practical usage for these concepts (Linn et al., 2015).

Research conducted by McNeill et. al. (2006) as affirmed by Masters and Docktor (2022), establishes strong evidence supporting the educational benefits of IBL. The study discovered that students who learned through inquiry-based science education achieved superior understanding of scientific concepts compared to students who took traditional courses. The research team emphasized that the learning framework of inquiry-based learning leads students to develop a more sophisticated comprehension of the subject matter by focusing on exploration and questioning and hands-on learning experiences.

Sampson and Clark (2009) conducted a study that investigated the effect of IBL on students' understanding of scientific argumentation and reasoning. The investigation determined that students who engaged in inquiry-based learning methods showed substantial progress in their ability to create and support scientific arguments. The researchers linked the educational advancement to the inquiry process because students continuously improved their comprehension by testing theories through experiments and logical deductions based on facts.

The beneficial learning outcomes of IBL become apparent when students can apply their knowledge in different real-world situations. Furtak et. al. (2012) discovered that IBL students showed superior abilities to use their understanding when facing new problems and contexts.

Deep conceptual understanding in students becomes apparent through knowledge transfer, which means they can apply their learning across different situations.

Students develop better understanding through technology integration in inquiry-based learning (Hamdan et. al., 2022) The combination of simulations with modeling tools and data analysis software provides students with interactive biological process visualizations and variable control features that surpass traditional educational approaches. Students can develop better conceptual frameworks when they use computer simulations to learn about dynamic cellular functions (Sotáková et al., 2020.)

The transferability of knowledge is a fundamental sign of deep comprehension because students can apply their learned principles effectively in various environments.

IBL educational approaches demonstrate improved conceptual learning through the implementation of technology. Students can observe the complexities of biological processes through simulations and use modeling tools to adjust various parameters which traditional classroom methods cannot achieve. Through computer simulations of cellular processes, students develop improved comprehension about dynamic cellular functions and interactions according to Sotáková et al., (2020).

2.4.3 Attitudes towards learning biology

Research demonstrates that students who participate in Inquiry-Based Learning (IBL) show better attitudes toward biology which leads to improved self-assurance and interest in learning the subject (Rong, 2021). When students participate in the learning process through IBL, they benefit from a teaching approach that establishes positive learning conditions.

The implementation of IBL methods leads to students developing more confidence and passion for learning biology (Kamath & White, 2023). Students who actively participate in scientific investigations develop greater interest in the material they are studying. According to Harlen (2015) students develop better understanding of biology when they independently discover concepts through Inquiry-Based Learning. The investigative learning method sparks more excitement and practical learning connections which builds students' passion for biology.

Students build their scientific skills through repeating the inquiry method of questioning, experiment design, data collection and conclusion-making which builds their self-assurance in science. Through their investigative success and developing understanding of biology, students gain the confidence to address complex problems more effectively. Harlen (2015) emphasizes that this confidence serves as the essential foundation to create positive learning attitudes in biology and motivate students to pursue advanced studies.

The implementation of IBL methods emerges as a proven method which significantly enhances student motivation and engagement levels in biology courses. A research work by Kumar and Johnson (2018) focused on observing how IBL impacted biology student motivation and engagement. The research discovered that students who participated in inquiry-based learning showed better learning motivation and classroom engagement compared to their peers who were exposed to traditional teaching methods. The active participation in scientific inquiry and the ability to explore individual areas of interest proved essential in boosting student motivation according to the study.

The higher levels of motivation and engagement which appear in IBL classes stem from various underlying elements. The first aspect of IBL enables students to direct their investigations independently which gives them complete ownership of their learning process. Students develop their intrinsic motivation through ownership because they actively participate and invest in studying when they choose their learning material (Printer, 2023). The learning approach of IBL creates an environment which enables students to work together to solve problems and discover new information which makes learning more interesting and socially beneficial. Students who work with their peers to tackle issues and exchange new findings experience better engagement levels and create a supportive educational setting (Gillies, 2016).

According to Ramos and Israel (2024), IBL classroom activities enhance student perceptions of biology as an academic subject. Students who participate in meaningful scientific investigations gain an enhanced understanding of biology's essential role in comprehending natural phenomena. Real-world applications of biological principles become more evident to students through inquiry-based learning activities which strengthen their positive academic perceptions. Biology becomes more meaningful to students when they conduct experiments about environmental changes and investigate genetic inheritance because these activities relate the subject to their everyday lives and global systems according to research by Wilson et al. (2010).

The enduring effects of IBL on student biology attitudes surpass short-term involvement because they create lasting attitudinal transformations. A research study conducted by Gibson and Chase in (2002) discovered that middle school students who participated in an inquiry-based science program continued to have positive scientific attitudes for multiple years after program completion. Students need to maintain their interest in biology throughout their academic journey in order to advance into higher educational levels and scientific professions.

2.5 Empirical Evidence of Inquiry-Based Learning Approach

Many researchers have focused on the impact of inquiry-based learning (IBL) on the academic achievements of biology students. Their studies have reported that IBL increases students' knowledge, memory, and attitudes towards biology, and it has frequently outperformed the traditional teaching styles. For example, 231 secondary school students from Rwanda participated in an experiment conducted by Manishimwe et al. (2023). According to this experiment, students who were taught using the 5Es IBL method made higher academic achievements because they had markedly higher post-test scores compared to students who were taught using traditional teaching methods.

In light of the former, Enebechi (2021) conducted research on the influence of IBL on the retention of Nigerian senior secondary school students in biology. The research found that pupils who were instructed through IBL performed better than their peers who were educated using traditional methods in terms of performance and retention of biological knowledge. According to a study by Mwenda and Ndayambaje (2021) explored how inquiry-based learning influences the learning outcomes of lower secondary biology students in Tanzania. The study discovered that IBL instructional methods led to superior academic results among students compared to the traditional educational approach.

Also, research conducted in the Delta Central Senatorial District of Nigeria to evaluate how inquiry-based learning and lecture methods influenced high school biology student achievement. Researchers employed a quasi-experimental pre-test, post-test control group study which included 320 senior secondary students. The research discovered that students in senior secondary school achieved higher test scores when they were taught using the inquiry technique compared to students who did not receive this instruction.

This means that the academic achievement of biology students can be promoted more successfully through the inquiry method. To find out the effectiveness of IBL on Biology Achievement, Naz et al. (2024) conducted a real experiment with 80 students in a Pakistani secondary school. For 8 weeks, the experimental group was taught using the ***5E*** inquiry learning model, whereas the control group was largely lectured. The effectiveness of IBL in promoting biology academic achievement is evident from the fact that the IBL group performed better on post-tests than the control group.

The influence of IBL on the attitudes of the students toward learning biology in upper secondary schools in Rwanda was studied by Manishimwe (2022). Pupils who were exposed to inquiry-based learning (IBL) had a better attitude towards biology compared to those who were taught in the customary manner. This change in the mindset is important because it can result in increased interest and academic performance. Freeman et al. (2014), also analyzed 225 studies to determine the efficiency of active learning (includes IBL), on students learning in science, technology, engineering, and mathematics (STEM). From the results, students in active learning did better in their tests and had fewer failures than those in traditional lectures. This shows how IBL is important as it can be applied in raising the achievement level of students in different scientific fields.

Furthermore, Issaka (2023) conducted research on how Inquiry Based Learning affected performance and retention in integrated science in Ghana. It was found that students who underwent IBL performed better and retained more information compared to those who underwent conventional lecture method. Abu (2023) also did a study to determine the effect of guided inquiry on students learning biology in Kogi State, Nigeria. He found that IBL had a positive effect on students' performance by showing that students taught using group guided inquiry method were better than those taught through lecture method when it came to test marks.

All of these reports support the findings that inquiry-based learning has a high effect on biology students' academic accomplishment. IBL is superior to ordinary teaching methods because it promotes critical thought, direct participation, and positive attitudes towards science.

2.6 Gender Differences in Inquiry-based Learning and Student Performance

While science teaching from a certain perspective might be generally believed to be free from issues of gender, some other spectrum of individuals believe that issues of gender and science teaching are rather persisting. For this reason, Mamo (2025) addresses the issues of gender in relation to academic achievement. According to Srinivasacharlu (2024) 'gender' refers to the socially-constructed roles, behaviours, activities, and attributes that society considers to be appropriate for men and women.

Hence, there is no real difference among students' academic performance in science. Almukhambetova (2024) discusses this in relation to the teaching of STEM in Kazakhstan.

Research on gender disparities in academic performance has increasingly emphasized the impact of instructional strategies, particularly inquiry-based learning, on student achievement (Javed, 2021). According to Baiden-Amissah (2023), it has been observed that gender has no significant impact on students' attitudes to biology; rather, teaching methods and students' determinations do play a significant role in influencing the attitude of students to biology compared to gender. This is aligned with previous findings by Husaini et al. (2015), Uitto (2014), and Nasr and Soltani (2011), who affirm that there was no significant difference between the male and female students in terms of interest, motivation, and engagement in biology.

Studies show that traditional teacher-centered teaching methods produce no significant gender differences compared to gender differences in IBL learning (Cooper et al., 2015; Nunaki et al., 2019). A study conducted by Cooper et al. (2015) on gender differences at a university in Georgia found no significant difference amongst male and female students in traditional teacher-centered strategies.

These results affirm that active learning techniques within IBL may foster a learning environment that is more supportive of both male and female learners to score higher grades in sciences and mathematics. In the same way, Nunaki et al. (2019) focused on investigating how IBL affects the metacognitive skills of high school learners. Their study shows that IBL is effective in enhancing the students' metacognitive skills without there being gender differences in metacognitive development. This is contrary to prior studies that have indicated that girls have higher metacognitive skills than boys (Bidjerano, 2005; Carr & Jessup, 1997). This shows that IBL could impact both male and female students equally in enhancing their critical thinking and problem-solving skills through teamwork.

Dian (2024) argues that the traditional methods of teaching cannot be "gender-biased". However, IBL technologies seems to be fair for both genders. Cooper et al. (2015) emphasized on active learning and problem-solving skills which is important in gaining student's attention, especially the females. Also, Nunaki et al. (2019) argue that IBL has many advantages for the development of essential cognitive skills without gender discrimination.

Given these discoveries, the study seeks to investigate the effect of IBL on male and female students' performance in biology.

2.7 Gaps in the Literature

Despite the increasing interest in inquiry-based learning (IBL), there is a notable deficit in the literature, especially in the field of biology education. This knowledge is critical in guiding the future direction of research in the field while improving the efficiency of IBL in classrooms.

One major gap is the lack of literature on the long-term effects of IBL on students' academic performance and attitudes towards biology. Many works have demonstrated the short-term benefits of IBL, such as increased interest and learning. However, there is still no evidence as to whether the effects last. For instance, Furtak et al. (2012) pointed out the need for a longitudinal study to follow students even after the end of a course to ascertain whether IBL has any lasting effects. In its absence, it is impossible to say if the early advantages translate into a high GPA or even an interest in science.

Another vast field of unexplored potential of IBL is its use in teaching molecular biology, known for its complexity and a number of highly abstract theoretical issues. The traditional methods of lectures and reading textbooks are not invariably effective in this area, as they require students to memorize lots of information. In contrast, IBL seems to be a very attractive alternative, as it implies a high level of students' active learning. For example, Roudabush and Kropp (2018) report that inquiry-based labs were significantly better at helping students learn about DNA replication and protein synthesis compared with conventional lecture-based classes. Still, the positive effects may be different in different types of situations, and there are relatively few studies that explore these aspects related to molecular biology.

Similarly, genetics education can greatly benefit from IBL because genetics is based on data and calculations. Genetic activities, such as gene mapping and analysis of inheritance patterns, can be perfectly executed if they have an element of inquiry. Lopatto (2008) found out that students that engaged in inquiry-driven genetics projects were shown to improve their problem-solving abilities and understand genetic concepts well. However, there is still the question of how IBL can fix common teacher misconceptions about genetics and how to accommodate new tools like bioinformatics. As such, more research is required.

The methods and effectiveness of IBL are not only limited to the content of the teachers. These two also have an effect on the outcomes of the IBL. They involve the methods employed in the classrooms, such as support from teachers, availability of materials and resources in the school, the social dynamics in the school, and many others. For instance, Windschitl and Braaten (2008) observed that the pedagogical content knowledge and self-efficacy of the teachers impact the outcomes of the IBL.

Some schools have a shortage of materials, equipment, and technology to use, while others have to face the great challenge of large classes and varying abilities of students, among many others. Such variations need to be studied, and possible solutions need to be given. This brings the need to study the best practices that the teachers can adopt to suit the IBL.

To cure these gaps, it is essential that the coming research focus on the creation of uniform assessment tools that can measure all the specific outcomes of IBL in biology, such as conceptual objects, technical inquiry, and also scientific technical objects. There is also a great need for longitudinal research to determine the durability of the impacts of IBL on students' academic performance and attitudes. In addition, professional development programs need to be strengthened to help teachers to develop the confidence and skills needed to implement IBL across different topics in biology.

2.8 Determinants of Inquiry-Based Learning (IBL) Implementation

The successful application of inquiry-based learning (IBL) in biology learning is determined by various intertwined aspects as presented below.

Firstly, IBL efficiency is based on the extent of the teacher's training and preparedness. Teachers have to transition from conventional methods to becoming facilitators of learning. In essence, teachers must have a comprehensive appreciation of inquiry methods, organizing a classroom effectively, and being capable of casting the learning process.

Blanchard et. al. (2009) underscored the significance of thorough and continued professional learning in equipping teachers with the skills for IBL. Having hands-on experiences in creating and delivering science inquiries and being coached and continuously held helped teachers become more confident. Even so, gaps are evident in the best training formats and the specific abilities educators need to boost IBL.

Again, the availability of resources is yet another basic necessity when it comes to IBL. Successful inquiry-based learning activities require laboratory equipment, appropriate technology, and scientific information sources. Schools without these resources may not deliver the best inquiry activities to the students. According to Crawford (2014), schools with well-equipped labs and digital facilities have an easier time implementing IBL. Addressing the resource question would require that strategies be put in place to provide the necessary equipment that schools need to facilitate learning activities. It would also require the development of appropriate policies and approaches for under-resourced institutions. Research is also necessary to establish cost-effective ways of ensuring that resource-strapped schools have access to the resources they need for inquiry-based learning activities. This still underscores the fact that there is a need for a supportive classroom culture for inquiry. Windschitl et. al. (2008) argue that inquiry thrives in an environment characterized by collaboration, dialogue, reflection, and discussion. In this setting, it is important to promote conversations, encourage risk-taking, and support group learning.

Creating a classroom environment that is inclusive and conducive to inquiry is quite challenging, especially where the population in the classroom is diverse and high. There is an urgent need for research on the specific strategies that can be used to create such environments in this context.

Also, institutional regulations and structural designs have a considerable influence on the adoption of IBL. In a more rigid educational system, with its emphasis on standardization and prescribed curricula as well as standardized tests, the teachers may not have the scope to frame a wonderful IBL activity for the students.

Decker (2020) discovered that schools with strong administrative support and flexible curricular policies were better suited to adopting IBL. In contrast, teachers in constrained environments faced impediments that hampered creativity. This emphasizes the significance of support systems at the school and district levels.

Moreover, most of the IBL research focuses on the short-term benefits of IBL in exams, students' engagement, and students' grasps (Furtak et al., 2012). However, there is little evidence on how the improvements have been sustained over time. Therefore, longitudinal studies are essential to evaluate the long-term impact of IBL on students' performance, careers, and attitudes. According to Zion et al. (2005), without students being tracked for a long time, the stakeholders cannot be able to get a complete picture of the IBL initiative and whether it is worthwhile to extend it to other subjects and areas. Research that follows students across a number of levels of education could yield key information about the long-term effects of inquiry-based learning.

Another critical precaution is that traditional evaluation techniques do not capture the intricate learning outcomes of inquiry-based learning. For instance, standardized tests often concentrate on the regurgitation of facts and do not assess the student's ability to acquire inquiry skills, critical thinking, and problem-solving techniques. Sotáková et al. (2020) talk about a crucial need to design new ways of evaluation that will match the goals of IBL, such as performance-based assessment, portfolios, reflective journals, rubrics aimed to show profound understanding or inquiry, etc. High-quality evaluation is required to show the significance of IBL and the necessity to provide appropriate education.

Technology has some powerful tools to help enhance IBL; these are in the form of simulations, software modeling, and data analysis. These tools can make abstract biological concepts more tangible, foster data literacy, and provide a virtual environment for experiments. Research conducted by Rutten et al. (2012) showed that simulations and models could improve the understanding of complex systems. Such tools as Virtual Cell Animation Collection (VCell) and Geographic Information Systems (GIS) have the potential to make learning about biological sciences more amusing and accessible.

However, the digital divide becomes a significant limit. Some schools might not have enough technologies that can integrate properly. Also, the teachers need training to use technology in the classwork under IBL (Hew & Brush, 2007). There is a need for research to help to integrate technology and IBL as well as develop technology as a scaffold to inquiry, not against it.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter outlines the research methodology employed to investigate the effects of the inquiry-based teaching approach on students' performance in biology. It also examines the effect of using IBL on gender differences in academic performance and explores students' perceptions of IBL in learning biology. The methodology includes the research design, population and sample, data collection instruments, procedure, and data analysis methods.

3.1 Research Design

This study employs a quasi-experimental design, specifically a non-equivalent control group design. This design is suitable because it allows for the comparison of outcomes between groups exposed to different instructional methods while acknowledging the practical constraints that may prevent random assignment.

A quasi-experimental design is chosen when random assignment of participants to groups is not feasible due to practical or ethical reasons (Shadish et. al., 2002). In educational settings, it is often challenging to randomly assign students to different instructional methods because classes are typically pre-determined by school schedules and policies. Therefore, a quasi-experimental design provides a viable alternative for investigating causal relationships in such contexts.

In this study, the non-equivalent control group design involves selecting two groups of students: one group (the experimental group) was taught using the inquiry-based learning (IBL) approach, and the other group (the control group) received traditional instructional methods. The term "non-equivalent" refers to the fact that the groups may not be identical in terms of their characteristics before the intervention begins, as random assignment is not used (Campbell & Stanley, 1963). However, both groups will be similar in terms of grade level, subject matter, and other relevant variables to ensure comparability.

The quasi-experimental design, specifically the non-equivalent control group design, is well-suited for this study as it allows for a practical and ethical investigation of the effects of the inquiry-based learning approach on students' performance in biology. By carefully selecting comparable groups and using rigorous data collection and analysis methods, the study aims to provide reliable and meaningful insights into the effectiveness of IBL.

3.2 Research Approach

This study employed a mixed-methods research approach by merging quantitative method with qualitative method to fully assess how inquiry-based learning (IBL) affects biology student performance and gender disparities as well as student viewpoints. The mixed-methods design was selected because it allows for a more robust analysis by combining numerical data with in-depth insights, providing a holistic understanding of the research problem (Creswell & Creswell, 2018). The quantitative component employed a quasi-experimental design to measure the impact of IBL on academic performance and gender influence while the qualitative component supplements the quantitative findings by exploring students' perceptions and experiences with IBL.

3.2 Study Area

The study was conducted at Winneba Senior High School, located in the Effutu Municipal area in the Central Region of Ghana. This school was selected due to its reputation for academic excellence and its willingness to participate in educational research initiatives. Winneba Senior High School is one of the leading secondary schools in the region, known for its robust science curriculum and well-equipped laboratories, making it an ideal setting for investigating the effects of inquiry-based learning (IBL) on students' performance in biology.

Effutu Municipal is an administrative district in the Central Region of Ghana. The municipality is known for its diverse population, which includes students from various socio-economic backgrounds. This diversity provides a rich context for examining the effect of IBL on different student demographics, including gender differences in academic performance.

Winneba Senior High School is well-equipped with the necessary resources to implement the IBL approach effectively. The school boasts modern science laboratories, a comprehensive library, and access to digital learning tools, which are essential for facilitating hands-on, inquiry-based learning experiences. The availability of these resources ensures that students can engage in practical experiments and interactive learning activities that are central to the IBL approach. The school also has a strong emphasis on science education, with dedicated and experienced biology teachers who are enthusiastic about incorporating innovative teaching methods into their curriculum. The administration's support for research and development in education further enhances the feasibility of conducting this study at Winneba Senior High School. The school's commitment to academic excellence and continuous improvement provides a conducive environment for implementing and evaluating new instructional strategies.

3.3 Population

The target population for this study was all senior high school students enrolled in biology courses at Winneba Senior High School. A purposive sampling technique was used to select two groups: one experimental group that was taught using the inquiry-based learning (IBL) approach and one control group that received traditional instruction.

3.4 Sample and Sampling Procedure

The sample was made up of 60 students, with 30 students in the experimental group and 30 in the control group. Within these groups, there was a balanced representation of boys and girls to examine the effects of IBL on gender differences in academic performance.

Table 1: Sample Groups for the Study

S/N	Group	Boys	Girls	Total students
1	Experimental group	10	20	30
2	Control group	12	18	30
	Total	**26**	**34**	**60**

The selection of the sample was critical to ensuring that the study results were generalizable to the broader student population. The sample size of 60 students was adequate to provide a reliable basis for statistical analysis and to detect significant differences between the groups (Creswell, 2014).

3.4.1 Experimental group

The experimental group, Home Economics 1, was made up of 30 students, including 12 boys and 18 girls. These students were taught using the IBL approach, which involved engaging them in hands-on activities, encouraging them to ask questions, and guiding them through the process of scientific inquiry. This approach was expected to enhance their understanding of biology concepts and improve their academic performance.

3.4.2 Control group

The control group, 2 Home Economics 2, also consisted of 30 students, with 14 boys and 16 girls. This group continued to receive traditional instructional methods, which typically involved teacher-centered lectures, textbook-based learning, and individual assignments. This method served as a benchmark to compare the effectiveness of the IBL approach.

3.5 Data Collection Instruments

To address the research questions, two data collection instruments were employed to ensure a comprehensive understanding of the effects of the inquiry-based learning (IBL) approach on students' performance, gender differences, and students' perceptions. These instruments were the Biology Achievement Test (BAT) and questionnaires.

3.5.1 Biology achievement test (BAT)

The Biology Achievement Test (BAT) was used to measure students' academic performance before and after the intervention. These tests were administered as pre-tests and post-tests to both the experimental and control groups. The pre-test was administered at the beginning of the study to establish a baseline of students' knowledge and skills in biology. This was done to help in identifying any initial differences between the experimental and control groups (McKenney, 2019). The pre-test was conducted during regular class periods to ensure that the testing environment is consistent for all students. The post-test on the other hand was administered at the end of the study period to measure any changes in students' performance. The result of the post-test was compared with the pre-test scores to assess the effect of the IBL approach on students' learning outcomes. Similar to the pre-test, the post-test was administered during regular class periods to maintain consistency. The BAT (pre-test and post-test) covered key topics in the biology curriculum, ensuring alignment with the instructional content. The test was designed to assess both lower-order cognitive skills (e.g., recall of facts) and higher-order cognitive skills (e.g., application, analysis). The test was developed in collaboration with biology teachers to ensure it is appropriate for the students' grade level and curriculum.

The researcher administered 25 multiple-choice test questions on transport (Circulatory System) before the start of the study, and all participants were asked to complete a pre-test to measure their baseline knowledge and perception in Biology. Participants were assigned to the IBL group and the lecture group. The pre-test was administered to both groups in the same way to ensure that there is no bias.

The researcher again administered 25 questions including multiple choice and practical test questions as BAT based on the items specification of the units specified after the completion of the study. The BAT (post-test) was administered to both groups in the same way to ensure that there is no bias.

3.5 2 Students perception questionnaires

A structured questionnaire was developed to gather data on students' perceptions of the IBL approach. The questionnaire will include both closed-ended and open-ended questions to capture a range of responses. The closed-ended questions will use a Likert scale to assess students' attitudes towards IBL, their engagement in the learning process, and their perceived effectiveness of the approach. For example, students might be asked to rate statements such as "I find inquiry-based learning more engaging than traditional methods" on a scale from 1 (strongly disagree) to 5 (strongly agree) (McKenney, 2019).

Also, the open-ended questions were to allow students to provide more detailed feedback on their experiences with IBL. The questionnaire will be administered to all students in the experimental group at the end of the study period. The administration of the questionnaire will take place during a dedicated session, ensuring that students have sufficient time to provide thoughtful and thorough responses. Students will be assured of the confidentiality of their responses to encourage honest and accurate feedback.

3.6 Validity of Research Instruments

According to Fraenkel and Wallen (2003), validation involved ensuring that the instruments were measuring what they were intended to measure and that they were reliable. The validation of the research instruments included consultations with experts and pilot testing.

The Students' Perception Questionnaire (SPQ) consisted of 20 items and was adapted from a previous study by Changeiywo et al. (2013). To validate the SPQ, an expert from the Department of Science Education with a rank of senior lecturer was consulted, in addition to the supervisory team who had already validated the instrument. The expert was tasked with checking for any errors in the questionnaire, ensuring that the questions accurately tested student motivation, and verifying that the items were suitable for the level of students being studied. Upon review, the expert deemed the instrument satisfactory and appropriate for the study.

The validation of the pre-test and post-test used in this study was an important step to ensure the reliability and validity of the test instrument. The BAT, consisting of 25 multiple-choice items focused on the topic "Movement of Substances into and out of Cells," was reviewed to ensure its effectiveness. The researcher reviewed the questions and content with an expert in the field of Biology Education. The expert provided feedback on the appropriateness and relevance of the questions for the topic being studied and suggested revisions to improve the clarity and accuracy of the questions.

The researcher also administered the pre-test and post-test to a pilot group of students who were not part of the study sample. The pilot group was similar in demographic characteristics to the study sample, and the results of the pilot test were used to assess the clarity and appropriateness of the questions. The validated pre-test and post-test were then administered to the study sample before and after the intervention to measure the effectiveness of the IBL approach compared to the lecture method. Overall, the validation process ensured that the instruments were reliable and valid measures of the student's knowledge and motivation in biology.

3.7 Reliability of Research Instruments

Reliability refers to the consistency and stability of a measuring instrument (Babbie, 2020). In this study, the reliability of the research instruments was established using a test-retest method, where the same set of instruments were administered twice to the same group of students at two different times (Wallen & Fraenkel, 2013). To establish the reliability of the pre-test and post-test instruments, a pilot study was conducted with a small group of students (n=10). The pilot test was conducted to assess the clarity of the questions, the time required to complete the tests and questionnaires, and to identify any possible errors or ambiguities in the instruments.

The tests were administered twice within a two-weeks interval, and the scores obtained were analyzed using the test-retest method. The reliability coefficient was calculated using the Pearson product-moment correlation coefficient (r), which measures the degree of correlation between two sets of scores. This method was also used to assess the reliability of the Students' Perception Questionnaire (SPQ).

The results of the pilot study showed a high level of consistency between the scores obtained from the pre-test and post-test, and the questionnaire, respectively. The reliability coefficient for the pre-test and post-test was 0.85, and that of the questionnaire was 0.87, which indicated a strong positive correlation between the two sets of scores (Babbie, 2020). This high level of reliability suggested that the instruments were consistent and stable over time.

By ensuring that the instruments used in the study were both valid and reliable, the study aimed to produce accurate and dependable findings.

3.8 Data Collection Procedure

The data collection for this study used a quantitative method, primarily through a pretest-post-test quasi-experimental design. This involved administering a pre-test to both the experimental and control groups, implementing the inquiry-based learning (IBL) intervention with the experimental group, and then administering a post-test to both groups to assess the effect of the intervention on students' performance on the topic " Transport (Circulatory system)".

Before the intervention, a pre-test was conducted to gauge the students' initial knowledge of the selected Biology topic. The pre-test included 25 multiple-choice questions based on the topic covered in the biology curriculum. This initial assessment established a baseline for comparing the intervention's effects on students' performance.

During the implementation phase, the experimental group received instruction using the IBL approach. This involved engaging students in hands-on activities, fostering inquiry, and guiding them through the learning process. The control group continued with traditional teaching methods, including teacher-centered lectures and textbook-based learning. This phase lasted for eight weeks.

The experimental group (2 Home Econs 1) was taught using the IBL approach, which included interactive and exploratory learning activities focused on " Transport (Circulatory system)" and the control group (2 Home Econs 2) received traditional instruction, which included lectures, note-taking, and textbook assignments on the same topic.

At the end of the eight-week intervention period, a post-test was administered to both the experimental and control groups. The post-test, identical to the pre-test, consisted of 25 multiple-choice questions on the same topic in the biology curriculum. The post-test measured the students' academic performance and assessed the effect of the IBL approach compared to traditional instruction.

Along with the pretest-post-test experimental design, a Likert-scale questionnaire was used to gather data on students' perceptions and motivation. This questionnaire was administered to both the experimental and control groups after the post-test. The questionnaire aimed to assess students' attitudes towards learning and their motivation levels following the intervention.

Finally, to ensure the validity and reliability of the data collection instruments, the pre-test, post-test, and questionnaire were pilot tested on a separate group of students not involved in the main study. The pilot test helped identify any weaknesses in the instruments, allowing the researcher to make necessary adjustments to enhance clarity and effectiveness (Fraenkel et al., 2019). By implementing this structured data collection procedure, the researcher ensured that comprehensive and reliable data were gathered to evaluate the effect of the inquiry-based learning approach on students' performance and motivation in the topic Transport (Circulatory system)

3.9 Pre-Treatment Stage

To begin the pre-intervention stage, the BAT (pre-test) was administered to all 60 students in both classes to measure their baseline knowledge in Biology. The pre-test was composed of 25 questions on the selected topic in Biology that were relevant to the study. The pre-test was administered in a standardized manner to both groups to ensure that there was no bias.

After the pre-test was administered, the 60 students from the two classes were assigned to the inquiry-based learning group and the traditional group. 2 Home Economics 1 was designated as the IBL group (experimental), and 2 Home Economics 2 was designated as the traditional learning group (control).

Before the treatment began, the students were informed about the study, its purpose, and their roles as participants. They were also assured of the confidentiality of their responses and that their participation was voluntary.

3.10 Treatment stage

The treatment stage lasted four weeks, during which four structured lesson plans were implemented. The experimental group received instruction through the Inquiry-Based Learning (IBL) method during this time period while the control group followed the standard lecture-based teaching approach. The two groups received the same content which included lessons about the circulatory system and they spent the same amount of time learning the material. The instructional materials used for both groups were the same; however, the methods of instruction differed. The treatment process extended through four weeks of time which made it more than just a single teaching session.

The final week required the administration of a post-test to both groups which students used to show their learning progress from the teaching period. In addition, a questionnaire was administered to the IBL group to evaluate their perception and motivation towards the inquiry-based learning method.

3.11 Implementation of the Treatment

During the treatment stage, two instructional methods were implemented: The Inquiry-Based Learning (IBL) Approach and the Traditional Teaching Method (TTM). Both methods were implemented for a specific period, after which a post-test was administered to assess student knowledge and motivation in Biology.

For the Inquiry-Based Learning Group, the implementation involved engaging students in active learning through questioning, exploration, and investigation. The subject matter was broken down into smaller units with clear learning objectives. Students were encouraged to formulate their own questions, design experiments, and seek answers through guided inquiry. They had regular interactions with the instructor, who provided immediate feedback and guidance. Self-assessment tools were made available to help students monitor their progress, and ample time was given for practice and review of the material.

For the Traditional Teaching Group, the implementation of the Traditional Teaching Method involved the teacher delivering lectures while the students took notes. The instructional materials were the same as those used for the inquiry-based learning group, but the students had limited interaction with the instructor during class time. They were given time to practice and review the material on their own.

The implementation of both methods was monitored to ensure that the procedures were followed consistently and fairly for both groups. After the intervention period, a post-test was administered to both groups to evaluate their knowledge and motivation in Biology. Additionally, a questionnaire was administered to the inquiry-based learning group to evaluate their perception and motivation towards the inquiry-based learning method.

Overall, the implementation of the intervention stage involved providing equal opportunities for both groups to learn using different instructional methods, monitoring the implementation to ensure fairness, and administering assessments to measure their knowledge and motivation in Biology.

3.11.1 Lesson by inquiry-based learning approach (IBL)

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Components of the Circulatory System

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end of the lesson, students will be able to:

1. *Identify the main components of the circulatory system. That is:*
    - *Blood*
    - *Heart*
    - *Blood vessels*
2. *Describe the main components of the circulatory system*

Materials: *The teacher provides students with videos, diagrams, and other resources that explain the key concepts and help students to understand circulatory system better. Stopwatch/timer, electronic blood pressure monitor, graph paper to determine the heart rate at rest and during an activity.*

Engagement (10 mins)

- Teacher introduced stimulating question to during the lesson
    - ➢ *What makes your heart speed up when you are in motion?*
- Teacher presented a brief video which shows a beating heart.
- Teacher instructed students to place their hands on their chest and observe their heartbeat.
- The Teacher then asked students the following questions:
    - ➢ What is the function of the heart?
    - ➢ What would happen if the heart stopped functioning?
- The students wrote down 2-3 questions regarding the circulatory system through their inquiry process.

Explore (15 mins)

Inquiry Activity: Measuring Heart Rate Before and After Exercise

Teacher asked students:

- Does physical activity affect heart rate?
- Why or why not?

Teacher tasked students to predict what happened in both situations.

Procedure

- Students measured their resting heart rate by counting their pulse 15 seconds and multiplying by 4.
- Teacher guided students to perform light physical activity (e.g., jumping jacks 30 seconds).
- Measure heart rate immediately after exercise.
- Rest 2 minutes and measure heart rate again.

Analysis

- Students recorded their heart rates before and after exercise using the electronic blood pressure monitor.
- Students plotted their data on simple line graph.

Discussion (15 mins)

- Teacher guided students to analyze findings:
  - ➢ *What happened to the heart rate after exercise?*
  - ➢ *Why do you think the heart beats faster during physical activity?*
- Teacher introduced the key components of the circulatory system (heart, blood vessels, blood).
- Teacher uses real-life analogy: Compare the circulatory system to highway system where blood transports oxygen and nutrients like cars delivering goods.
- Teacher answered student-generated questions from the ***Engage phase***

Group Activity (10 mins)

Teacher guided students to undertake the following activities:

- Mini-research with short article excerpts.

Design a poster or infographic on circulatory system health.

Evaluation (10 mins)

To demonstrate the understanding of circulatory system by students, teacher evaluated students by asking them the following questions?

- Why does heart rate increase during exercise?
- Explain how blood moves through the circulatory system.

Self-Assessment

Students evaluated their learning outcomes while tracking which questions, they resolved from the beginning of the lesson.

3.12 Data Analysis

The data analysis involved both quantitative and qualitative methods to comprehensively address the research questions. This mixed-methods approach ensured a thorough understanding of the effects of the inquiry-based learning (IBL) approach on students' performance, gender differences, and perceptions.

First, descriptive statistics, including mean and standard deviation, were used to summarize students' performance data from the pre-tests and post-tests. This provided a clear overview of the central tendency and variability of students' scores (Creswell, 2014).

Again, inferential statistical methods were employed to compare the pre-test and post-test scores between the experimental and control groups. Specifically, t-tests were used to determine if there were significant differences in performance within and between the groups. These statistical analyses helped to identify whether the IBL approach had a significant effect on students' learning outcomes compared to traditional methods (Coe et. al., 2021).

Finally, questionnaire responses were analyzed using thematic analysis to identify common themes and patterns in students' perceptions of the IBL approach. Thematic analysis involved reading through the responses, coding key phrases, and grouping these codes into broader themes. This method provided insights into students' attitudes and experiences with the IBL approach (Creswell, 2014).

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS

4.0 Overview

This chapter presents the results of the data analysis, which includes both quantitative and qualitative data collected during the study. The objective is to evaluate the effects of the inquiry-based learning (IBL) approach on students' performance in biology, gender differences in academic performance, and students' perceptions of the IBL approach. The data were analyzed using descriptive and inferential statistical methods to test the research hypotheses and draw meaningful conclusions.

4.1 Quantitative Data Analysis

4.1.1 Descriptive statistics

Table 2 provides a summary of the experimental (IBL) and control (traditional instruction) groups' pre-test and post-test score descriptive statistics.

Research Question One: *What is the effect of inquiry-based teaching approach on students' performance in biology?*

To answer this question, a pre-test and post-test were conducted based on the selected topic in Biology that were relevant to the study. The results were analyzed using mean and standard deviation.

Table 2: Descriptive Statistics of Pre-test and Post-test Scores

Group	Test	N	Mean	SD
Experimental (IBL)	Pre-test	30	65.1	10.2
Experimental (IBL)	Post-test	30	80.2	8.30
Control	Pre-test	30	64.5	9.51
Control	Post-test	30	70.3	9.31

The result obtained from ***Table 2*** indicates that the pre-test means of the experimental group 65.1 and a standard deviation of 10.2 showed moderate dispersion in the students' initial performance. Upon using the inquiry-based learning approach, the post-test scores markedly increased to 80.2, with a reduced standard deviation of 8.30. This progress indicates not only a substantial improvement but also greater consistency in students' understanding. In the control group, the pre-test mean score was 64.5 with a standard deviation of 9.51, showing that the baseline knowledge was quite similar to the experimental group. However, the mean post-test scores only advanced to 70.3, with a standard deviation of 9.31. While there is a performance increase, it is less pronounced compared to the experimental group, and the variation in scores remains similar.

4.1.2 Inferential statistics

To test the null hypotheses, inferential statistical methods were employed, including paired sample t-tests in ***Table 3***.

$H_0$1. *There is no statistically significant difference in the effect of inquiry-based teaching approach on students' performance in biology.*

Data was computed and analyzed using paired sample t-tests to compare the mean performance scores of the experimental group before (pre-test) and after (post-test) the implementation of the inquiry-based learning (IBL) approach.

Table 3: Paired Sample T-test for Pre-Test and Post-Test Scores

Groups	Test	MD	t-value	p-value
Experimental	Pre-test vs Post-test	15.0	10.5	0.001
Control	Pre-test vs Post-test	5.51	3.23	0.002

The ***Table 3*** shows results from paired samples t-test which compared student scores from their pre-test test to their post-test between the experimental group and control group. The results demonstrated that students who learned through the Inquiry-Based Learning (IBL) method achieved an average improvement of 15.0 points which reached statistical significance (t = 10.5, p = 0.001). The control group students also achieved statistically significant score improvements between their initial test and their final test results (t = 3.23, p = 0.002). The control group students achieved an average score increase of 5.51 points which remained below the experimental group's score development.

The experimental group achieved a much higher average score increase which shows that Inquiry-Based Learning delivers superior biological academic results than standard teaching approaches. The results show that both teaching methods helped students learn but IBL students achieved better learning outcomes than students who used traditional teaching methods.

Table 4: Independent Samples t-Test Comparing Post-test Scores of Experimental and Control Groups

Groups	N	Mean	SD	t-value	p-value
Experimental	30	15.0	8.30	4.35	< 0.001
Control	30	5.51	9.31		

Table 4 showed that students who learned through Inquiry-Based Learning achieved different post-test average results than students who used the standard teaching approach. The experimental group students (M = 80.2, SD = 8.30) achieved higher performance than the control group students (M = 70.3, SD = 9.31) based on statistical analysis $t(58) = 4.35$, $p < 0.001$. The study results show that instructional methods directly influenced student achievement because random factors did not produce the performance differences (Anning et. al., 2024)

The experimental group showed better performance on average with less variety in their results which proves that IBL methods led students to achieve superior results and develop consistent knowledge about circulatory system concepts. The IBL method allows students to actively participate in inquiry and experimentation and guided discovery which helps them achieve better comprehension of biological concepts and better memory retention. The traditional method which focuses on teacher-centered instruction did not produce the same learning results as the other method.

Research Question Two: *What is the effect of using IBL on gender differences in the academic performance of students in biology*?

After the intervention Post-test scores were obtained after the intervention to measure the academic performance of students in the experimental group following the inquiry-based learning approach. This aimed to establish whether the IBL approach had differential impacts on academic outcomes based on gender. The analysis focused on comparing the post-test scores between male and female students to determine if significant differences in performance existed due to the IBL intervention. The findings of this analysis are presented in the ***table 5*** below**.**

Table 5: Descriptive Statistics of Post-test Result for Gender Difference in the Experimental Group

Gender	N	Mean	SD
Male	11	79.1	8.52
Female	19	81.2	7.54

Table 5 indicated that the mean score for male students in the post-test was 79.1 with a standard deviation of 8.52, whereas the female students had a slightly higher mean of 81.2 and a standard deviation of 7.54. These results reveal that, on average, female students in the IBL method slightly outperformed male students. However, the relatively close mean scores indicate that the IBL approach was effective for both genders, resulting in high academic performance overall. The similar values of the standard deviations suggest a comparable spread in performance within each gender, further indicating that the IBL approach was consistently effective across genders. Overall, these findings suggest that IBL applied to biology education does not create significant gender differences in academic outcomes, and both male and female students benefit equally from its application.

$H_0$2: *There is no statistically significant difference in academic performance between male and female students in biology under the influence of Inquiry-Based Learning (IBL).*

The data was obtained by conducting independent t-test to compare the post test scores of male and female students in the experimental group (IBL).

Table 6: ***Independent Samples t-Test Result for Gender Difference in the Experimental Group***

Gender	N	Mean	SD	t-value	p-value
Male	11	79.1	8.52	1.213	0.231
Female	19	81.2	7.54		

Table 6 depicted that the mean post-test score of male students was 79.1, with a standard deviation of 8.52. The female students had a slightly higher mean score of 81.2 with a standard deviation of 7.54. The t-value was 1.213, supported by the p-value of 0.231, concluding that there is no statistical difference in the mean scores of male and female students. Since the p-value is greater than the common level of significance at 0.05, we fail to reject the null hypothesis, suggesting that the variation might have occurred by chance. The implication of this finding is that gender did not significantly affect the effectiveness of the IBL approach in improving academic performance in biology. Male and female students benefited equally from the IBL approach. In general, the results indicate that IBL is a fair instructional practice that encourages equitable academic outcomes among both genders.

4.2 Qualitative Data Analysis

Qualitative data were collected through questionnaires and classroom observations to gain insights into students' perceptions of the IBL approach.

4.2.1 Students' Perceptions of IBL (Likert-Scale Items)

Research Question Three: *How do students perceive the use of IBL in learning biology?*

The perception questionnaire was conducted among the students to respond to this research question, which touched on several aspects of the IBL approach with respect to their experiences in biology. An analysis was conducted using frequencies and percentages of students' responses to provide an overview of the students' perceptions and the effectiveness of IBL as a teaching method. ***Table 6*** below gives a summary of the results.

Table 7: ***Descriptive Results of the Questionnaire on Students' Perceptions of Inquiry-Based Learning (IBL)***

No.	Statement	SD (1)	DA (2)	N (3)	A (4)	SA (5)
		N (%)	N (%)	N (%)	N (%)	N (%)
1	IBL made the lessons more interesting and interactive.	2 (3.3%)	3 (5%)	5 (8.3%)	25 (41.7%)	25 (41.7%)
2	IBL helped me better understand complex biological concepts.	1 (1.7%)	4 (6.7%)	6 (10%)	27 (45%)	22 (36.7%)
3	I felt more engaged in the learning process with the IBL approach.	2 (3.3%)	2 (3.3%)	7 (11.7%)	28 (46.7%)	21 (35%)
4	IBL encouraged me to think critically about the material.	1 (1.7%)	5 (8.3%)	6 (10%)	26 (43.3%)	22 (36.7%)
5	The hands-on experiments in IBL enhanced my learning experience.	1 (1.7%)	3 (5%)	4 (6.7%)	24 (40%)	28 (46.7%)
6	I found it easier to apply what I learned in real-world contexts.	1 (1.7%)	4 (6.7%)	6 (10%)	27 (45%)	22 (36.7%)
7	IBL helped improve my problem-solving skills in biology.	2 (3.3%)	3 (5%)	5 (8.3%)	26 (43.3%)	24 (40%)
8	Collaborating with peers during IBL activities was beneficial for me.	2 (3.3%)	3 (5%)	5 (8.3%)	25 (41.7%)	25 (41.7%)
9	I felt more confident in my understanding of biology after using IBL.	1 (1.7%)	4 (6.7%)	7 (11.7%)	26 (43.3%)	22 (36.7%)
10	IBL made learning biology more enjoyable for me.	2 (3.3%)	3 (5%)	6 (10%)	24 (40%)	25 (41.7%)

Key: SD= Strongly Disagree, DA = Disagree, N= Neutral, A= Agree, SA= Strongly Agree.

Analysis of ***Table*** *7* reveals that most of the students had an affirmative perception toward the implementation of the Inquiry-Based Learning (IBL) approach in biology class. From the statement "IBL made the lessons more interesting and interactive," 83.4% agreed or strongly agreed, meaning almost all students found the lessons to be interesting. Likewise, 81.7% of the students reported that IBL made it a lot easier for the understanding of complex biological concepts, signifying that the method did enhance learning. Moreover, 81.7% agreed or strongly agreed that they were much more interactive when learning through the IBL approach, indicating that the IBL approach succeeded in making the students much more participative in their learning. Additionally, 80% of the students answered that the content they learned through IBL encouraged them to think critically, suggesting that this type of learning fosters higher-order thinking. The hands-on nature of IBL was particularly appreciated, with 86.7% of students admitting that practical experiments made a significant contribution to their learning process, highlighting the practical exercises as a key factor in the perceived effectiveness of IBL. Similarly, 81.7% of the students stated that using IBL helped them to understand more clearly how to apply what they are studying to real situations, thereby greatly decreasing the theory-practice gap with IBL. Regarding the capacity for biological problem solving, 83.3% of students reported improvement. Collaboration was also received positively, with 83.4% of students agreeing that working with peers in IBL activities was beneficial, underlining the importance of cooperative learning associated with this approach. Finally, 81.7% of students found that IBL made learning biology more enjoyable, suggesting that the approach not only enhances learning but also makes it more pleasurable.

4.2.2 Students' Perceptions of IBL (Open-Ended Questions)

Hence, in the perception questionnaire, some questions were left open-ended for the respondents to further express their experiences of the students in the IBL approach, including the benefits, difficulties, or suggestions, in their own words. This was then analyzed for responses and perceptions to be summarized by common themes in Table 8 below.

Table 8: Students' Perceptions of Inquiry-Based Learning (IBL

Theme	Frequency	Percentage	Summary of Responses
Increased Engagement	40	66.7%	Many students reported feeling more engaged and motivated during lessons with IBL.
Enhanced Understanding	35	58.3%	Students expressed that IBL helped them better understand complex biological concepts.
Hands-On Learning	32	53.3%	The majority of students appreciated the hands-on experiments, finding them beneficial for learning.
Critical Thinking Development	30	50.0%	Responses highlighted that IBL encouraged them to think more critically about the material.
Collaboration with Peers	28	46.7%	Students valued the opportunities to collaborate with peers, noting it improved their learning.
Application to Real-World Contexts	25	41.7%	Students mentioned that IBL helped them apply what they learned to real-life situations.
Challenges with Time Management	15	25.0%	Some students found managing the time required for IBL activities challenging.
Need for More Guidance	12	20.0%	A portion of students felt they needed more guidance from teachers during IBL activities.
Overall Enjoyment	45	75.0%	A large number of students reported that IBL made learning biology more enjoyable.

Table 8 revealed that the majority, 66.7%, found that they were more motivated and interested in lessons. Another dominant theme, which was identified as being brought

about by IBL activities, was the better comprehension of complex biological concepts, mentioned by 58.3% of students. Other findings indicated that 50.0% and 46.7% of the students felt that critical thinking development and peer collaboration, respectively, greatly enhanced their learning with IBL methods. Another 41.7% of students found the material's real-life applicability useful in relating the classroom work with daily life. However, a few challenges were noted: 25.0% of students indicated that they had time management problems with IBL activities and 20.0% needed more guidance from teachers. Overall, 75.0% of the students recognized that their study in biology was more interesting with IBL, hence there was general acceptance of the method. On the whole, data are indicative that IBL could enhance the engagement, understanding, and enjoyment of students effectively, while paying sufficient attention to time management and guidance in the process of implementation.

4.3 Discussion of Results

The data obtained from the study were examined and the findings were presented in section 4.1. and 4.2. This section focuses on the quantitative and qualitative data analyses. The results were analyzed in order of research questions and hypothesis.

The first research question examined how inquiry-based learning (IBL) methods affected student performance in their biology. The research results showed that students who learned through IBL achieved better academic results than students who learned through traditional teaching approaches. The results show that students who learn through inquiry-based methods develop better knowledge about biological subjects. Students who learned through IBL achieved better results because they actively participated in their learning process which allowed them to investigate things and ask questions and conduct experiments and think about their experiences.

The observed improvement in students' performance following the implementation of IBL suggests that the approach promotes deeper conceptual understanding rather than surface learning. Students must build their own knowledge through inquiry-based activities which create opportunities for them to learn in a meaningful way. The research results match the findings of Minner et al. (2010) who presented those students who learned through inquiry-based science education achieved better conceptual understanding than students who learned through standard teaching approaches. Nicol (2021) discovered that inquiry-based activities help students understand scientific principles better because they can create their own interpretations through discovery and exploration. The present study results show that IBL teaching methods lead to better biology academic results because students learn actively while they develop their critical thinking abilities.

The research shows that students who learn through traditional teaching methods achieve shorter learning progress because teacher-led lessons fail to help students from different backgrounds learn effectively. Traditional instruction focuses on content delivery which restricts students from actively exploring biological concepts through hands-on activities. Student learning achievement differences will continue to exist because teachers who fail to include students in their teaching methods will not achieve their educational goals.

The results discovered that students who learned through inquiry-based methods showed a statistically significant improvement when they took their first null hypothesis test on biology subjects. The student progress from IBL exposure developed through a planned teaching strategy which showed no indications of random development. The research supports previous studies which demonstrated that inquiry-based learning methods help students learn better and stay more focused during their academic work (Minner et al., 2010; Nicol, 2021). Students learn better through hands-on work and experimentation in IBL which helps them learn biology concepts more effectively.

The second research question investigated the effect of inquiry-based learning on gender differences in academic performance in biology. The research findings showed that female students achieved slightly better results than male students but their academic performance differences lacked statistical importance. The research findings show that students achieve equal learning results through inquiry-based educational methods when they use this approach. The students achieved similar results which demonstrated that IBL education methods create a fair learning environment which supports all students regardless of their gender identity. This confirms Nasr and Soltani (2011) who found no gender differences in terms of biology engagement.

The study found no major gender differences an indication that inquiry-based learning promotes teamwork-based problem-solving which allows students share equal roles in the learning process as indicated by Cooper et. al. (2015). Educational activities which actively involve students in learning distribute learning chances at equal levels to reduce student differences in their academic performance. The research results show that science education through inquiry-based teaching methods creates an inclusive learning environment which treats all students equally (Nunaki et. al., 2019).

The third research question explored students' perceptions of the use of inquiry-based learning in biology. The research results showed that most students developed positive attitudes toward the IBL teaching method. Students told me that IBL transformed their biology classes into more exciting and hands-on learning experiences which demonstrated the method's success in boosting their motivation and participation. The research findings support Riga's (2020) statement which says students need interactive learning experiences to stay interested and motivated according to Tairab and Al-Naqbi (2017).

Students also perceived that inquiry-based learning improved their understanding of complex biological concepts. Students who learn through IBL get to research things personally which helps them build their understanding of subjects at a deeper level. The research findings support Nicol (2021) work which shows that students develop knowledge through active exploration during inquiry-based activities. Students reported better learning process engagement which Minner, Levy, and Century (2010) found to be a result of inquiry-based teaching methods which increased student motivation and engagement.

The inquiry-based learning method helped students develop critical thinking abilities which became their main advantage. Students in the IBL program stated that the approach helped them develop better critical thinking skills about biological concepts. The result stems from the fact that inquiry-based learning requires students to develop their abilities in solving problems and testing hypotheses and basing their reasoning on evidence. The research findings support Cabello et al. (2018) who proved that inquiry-based teaching methods help students develop their critical thinking abilities. The practical activities which IBL requires students to perform help them understand theoretical concepts through actual experience according to Quintana et. al. (2018). The students found that inquiry-based learning helped them use their biological knowledge for practical applications in actual life situations. Science education through IBL becomes more practical because students learn to apply their academic knowledge for their daily life needs. The research findings agree with the studies from Sotáková et. al. (2020) and Škoda et. al. (2015) which demonstrated that students achieve better understanding of scientific concepts through actual real-world experiences.

The research findings revealed collaboration as the main theme which students recognized during their study. Students who worked with their classmates during inquiry activities achieved better learning results because Vygotsky (1978) based his social constructivism theory on how people develop cognitively through their interactions with others. Students who work together on inquiry activities can share their thoughts while they test their beliefs and develop common knowledge.

The study revealed positive feedback about inquiry-based learning yet students encountered specific difficulties during their learning process. The students encountered two main problems which involved their ability to handle their time effectively and their requirement for extra teacher support during their research work. The research shows that IBL supports student independence but teachers must provide proper support and teaching methods to make it work. Nevertheless, the majority of students reported that inquiry-based learning made biology lessons more enjoyable, which aligns with the observations of Black et. al. (2018) regarding the relationship between enjoyment, engagement, and learning outcomes.

The research findings demonstrate that students who learn through inquiry-based methods achieve better academic results while developing higher interest in their studies and better skills to use biological concepts in practice. The method promotes deep learning because students need to build their own understanding instead of following traditional memorization techniques. The research shows that students achieve meaningful learning through their ability to associate new information with their existing knowledge and their capability to use this information in different situations (Bransford et al., 2022). Students showed continued interest in their inquiry work which proved that IBL serves as an effective educational approach (Aker & Ellis, 2019). The collaborative nature of inquiry-based learning also fosters communication and teamwork skills, as emphasized by Johnson and Johnson (2009).

The research findings show that inquiry-based learning methods help students understand better while they become more interested in learning and they develop their critical thinking abilities and they can use biological concepts in real-life situations. The conclusion matches the findings of Gilchrist et al. (2015) who found that students achieve deep understanding together with critical thinking skills through inquiry-based learning methods. Biology education achieves its highest potential through inquiry-based learning which serves as an effective teaching method to clarify biological concepts and teach students skills for continuous learning.

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CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter deals with a summary of this research work, the conclusion, recommendations proposed by the researcher and suggestions for further studies

5.1 Summary

The study aimed to explore the effect of IBL on students' performance in some selected topics in biology education. In this regard, the study sought to find out the effect of IBL on both academic achievement and gender differences, as well as to explore students' perception of this educational approach in Winneba Senior High School in the Effutu Municipality of Ghana.

IBL is basically based on constructivist theories of education. which emphasize students' meaningful activity in learning through exploration, questioning, and experimentation. The potential for IBL to really transform biology education into one that embeds deeper conceptual understanding and fosters critical thinking skills in learners was therefore the driving factor in carrying out this research. Specific objectives were to:

1. Assess the effect of IBL on students' performance in biology.
2. Analyze the effect of IBL on gender disparities in academic performance.
3. explore how students perceive IBL about biology learning.

The researchers applied quasi-experimental design which featured non-equivalent control groups. The research involved a sample of 60 students who split equally between two groups one taught through IBL and the other using traditional methods.

Data collection method includes pre-tests, post-tests, perception questionnaires and classroom observations. The researcher analyzed the collected data through descriptive statistics and inferential statistics which included paired t-tests.

The experimental group students demonstrated a statistically significant improvement in their academic performance compared to their peers in the control group.

More specifically, the mean post-test scores of the experimental group were far above their pre-test mean scores, thus indicating that IBL effectively enhanced the students' understanding of concepts in biology. This supports previous studies, such as Minner et al. (2010), which found significant improvements in student performance with inquiry-based instruction.

Data collection was done through pre-test and post-test, questionnaires of student perception, and classroom observations. The Biology Achievement Test administered to the two groups before and after the treatment measured academic performance. Perception questionnaires involved Likert scale items with open-ended questions in an attempt to elicit students' attitudes and experiences related to IBL. Classroom observations provided a qualitative insight into student engagement and comprehension during lessons.

Analysis of the pre-test and post-test score data showed that students who were instructed using the IBL approach had better results in the biology test. The mean post-test score for the experimental group was significantly higher compared to that of the control group, hence proving that the IBL approach is more effective in enhancing the understanding of biology concepts among students than the traditional methods. The findings are supported by previous studies; for instance, Minner, Levy, and

Century, 2010, have reported that students exposed to inquiry-based science instruction showed greater gains in their understanding of scientific concepts.

The study found no significant gender differences in the effectiveness of IBL. Both male and female students in the experimental group performed similarly well, suggesting that IBL is an inclusive teaching strategy that supports equitable learning outcomes. This finding is critical in addressing concerns about gender disparities in STEM education. Previous studies have highlighted that IBL can be particularly beneficial for engaging female students in science, supporting the idea that IBL promotes gender equity in the classroom.

The perception questionnaires revealed that, in fact, students had overwhelmingly positive perceptions of the IBL approach. An overwhelming majority of students responded that IBL was for them more engaging and enjoyable than classical education. The students appreciated the interactivity of the lessons, hands-on experiments, and the possibility of collaboration. On the other hand, it was also found that the use of IBL practices helped improve critical and problem-solving skills, with students feeling more confident in applying biological concepts to real-world scenarios. These views are supported by the works of Hmelo-Silver et al. (2007) observed that IBL increased capabilities of the students to think critically and independently.

General observations during the intervention process indicate that students were highly involved, very participative, and comprehended the subject matter well. The following features are regularly noted throughout the sessions: proper use of scientific terminologies and relating classroom lessons to real life. As such, this finding therefore provides evidence that, in addition to improving academic achievement, IBL also enhances deeper or functional knowledge in biology. The classroom observation also supports the same effect concerning the positive effects of IBL on student engagement and understanding, as has been reported in the student questionnaires.

5.2 Major Findings

1. The research findings demonstrated that students in the IBL group significantly outperformed the group taught using traditional methods in terms of their academic achievement in biology. As compared to their respective pre-test scores, the experimental groups' mean post-test scores were much higher, which amply demonstrates that IBL is a successful strategy for improving students' comprehension and memory of biological ideas. Since learners are actively involved in the process, this result supports the assertion that IBL enhances deeper learning.
2. There were no differences between male and female students with respect to the IBL approach; this shows that there were no significant differences in the performance of their students. This goes on to prove that IBL is one of the equitable teaching strategies that supports the learning of all students without any difference based on gender. What makes the case of IBL being an inclusive method for improving STEM education outcomes highly relevant to addressing gender imbalances in science education is that between the genders, there were no major differences.
3. The IBL approach was viewed positively by the majority of pupils. The practical exercises were valued by the students, who felt that they helped them comprehend difficult biological ideas. Students also reported that IBL promoted critical thinking and problem-solving abilities, which enhanced the enjoyment and significance of the learning process. These favourable opinions

highlight how IBL can raise student interest and enthusiasm in scientific classes.

5.3 Conclusion

The purpose of this study was to investigate the effects IBL on form 2 students' performance in biology. It was found that students taught using the IBL approach performed significantly better academically than those students instructed using traditional instructions. Major gains in post-test scores within the experimental group prove that IBL does guarantee profound learning through involving students in the exploration and investigation of scientific concepts. Indeed, this finding agrees with the literature in claiming the efficiency of IBL in deepening understanding and retaining the content of learning.

The results of the study have also indicated that there is no difference in the efficiency of IBL regarding gender. That means it includes everybody and works for all, therefore being equitable in its benefits towards students of both genders. In this regard, there is potential of IBL to narrow and decrease gender gaps in STEM education and hence becomes such an important tool in promoting equity inside classrooms.

This is further supported by the fact that students have positive perceptions about IBL as a teaching strategy. Most of the students said that IBL made learning more engaging, interactive, and enjoyable, hence increasing their motivation to learn and participate in class. Several students highly acknowledged the hands-on and collaborative nature of IBL as contributing to its appeal because students were able to be part of their education actively and build important competencies other than solely knowing the content.

5.4 Recommendations

Based on the findings and conclusions of this study, the following recommendations were proposed:

There should be proper provision of facilities which are necessary for effective inquiring strategies.

1. Creative and more effective learner-centered instructional strategies such as the IBL should be employed by biology teachers at Winneba Senior High and all other senior high schools to promote meaningful learning of biology.
2. Both genders must be encouraged to use IBL in learning difficult concepts in biology.
3. The study also shows that, IBL is an effective teaching method in straightening conceptions in biology

5.5 Suggestions for Further Studies

The study can be expanded in several ways to enhance its scope and findings.

1. Although this study was focused on biology, further research can be done in the future on how effective inquiry-based learning is across other branches science subjects, for example, in chemistry, physics, or environmental science.
2. There is a need to test the effectiveness of IBL in schools differing in terms of availability of resources, type of students handled, and whether located in urban or rural areas. The research will enable one to know how IBL performs in different contexts.
3. Research can be conducted on the attitudes of teachers towards IBL and the challenges they face in trying to practice it in the classroom. Study in understanding teachers' perspectives and the obstacles that they face definitely

will aid in the designing of resources and putting in place support mechanisms that enable an effective induction to the use of IBL.

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APPENDICES

APPENDIX I

WINNEBA SENIOR HIGH SCHOOL

BIOLOGY ACHIEVEMENT PRETEST (BAT)

SECTION A: Bio-data

Name: ………………………………………………………………………………….

Class: ………………………………… Date: …………………………………..

Instructions: Answer all questions. Choose the single best option.

1. The main job of your blood circulation network is to:
   a) Help digest meals
   b) Move oxygen and food to cells
   c) Make hormones work
   d) Store body energy
2. In our bodies, which organ works like a pump to move blood?
   a) The brain
   b) The liver
   c) The heart
   d) The lungs
3. When blood leaves the heart full of oxygen, it travels through:
   a) Thin capillaries
   b) Valves that open and close
   c) Veins returning blood
   d) Thick-walled arteries
4. Doctors call the yellowish liquid part of blood:
   a) Lymph fluid
   b) Blood plasma
   c) Haemoglobin solution
   d) Watery serum
5. What gives blood its red colour?
   a) Platelet fragments
   b) Iron-containing haemoglobin
   c) White blood cells
   d) Dissolved plasma salts
6. When germs enter your body, which blood cells attack them?
   a) Oxygen carriers
   b) Infection-fighting leukocytes
   c) Clot-forming cells
   d) Plasma proteins
7. Microscopic blood vessels where oxygen swap happens are
   a) Tiny capillaries
   b) Major arteries
   c) Returning veins
   d) Heart chambers
8. The pulse would speed up when you begin jogging as a physical activity.
   a) It slows down
   b) It becomes irregular
   c) It speeds up
   d) It stays steady
9. Anaemia is a prevalent blood disorder in Ghana which causes low red cell levels to produce fatigue.
   a) Haemophilia
   b) Anaemia
   c) Hypertension
   d) Leukaemia

10. The leg veins include tiny valves which serve which purpose?
    a) To push blood faster
    b) To stop backward flow
    c) To make new blood
    d) To store nutrients
11. Myocardial infarction stands for
    a) A stroke
    b) Clogged leg arteries
    c) A heart attack
    d) High blood pressure
12. Blood containing oxygen after lung passage moves to the heart's first chamber which is the:
    a) Lower left chamber
    b) Upper left atrium
    c) Right pumping chamber
    d) Right receiving area
13. The "lub-DUB" sound which doctors hear during check-ups originates from.
    a) Heart valves snapping shut
    b) Air in lungs
    c) Food moving in gut
    d) Muscle twitches
14. How many times per minute should a healthy adult's heart beat while at rest?
    a) 200-250
    b) 120-150
    c) 20-40
    d) 60-100
15. A cut on the skin causes which blood element to generate the scab?
    a) Red cells
    b) Plasma
    c) Platelets
    d) White cells
16. The heart receives used blood from your body through the…
    a) Left atrium
    b) Left ventricle
    c) Right atrium
    d) Right ventricle
17. The largest blood vessel in the human body which carries blood away from the heart is called…
    a) Coronary artery
    b) Aorta
    c) Jugular vein
    d) Pulmonary artery
18. People who use blood thinners need to consume foods containing Vitamin K.
    a) Vitamin D
    b) Vitamin K
    c) Vitamin C
    d) Vitamin A
19. Lab tests showing hypercholesterolemia indicate that someone has:
    a) Low iron levels
    b) High fat in blood
    c) Too many white cells
    d) Thin blood
20. The blood vessel which carries oxygen-depleted blood toward the lungs is the…
    a) Aorta
    b) Coronary vein
    c) Pulmonary artery
    d) Pulmonary vein
21. In emergency blood donations, which type can usually be given to anyone?
    a) Type O
    b) Type A
    c) Type AB
    d) Type B

22. When nurses check your pulse, they're feeling your:
    a) Capillaries
    b) Any visible vessel
    c) Arteries
    d) Veins
23. What special arteries feed the heart muscle itself?
    a) Renal
    b) Hepatic
    c) Pulmonary
    d) Coronary
24. Which of these activities would make your heart race fastest?
    a) Reading quietly
    b) Sprinting 100m
    c) Eating fufu
    d) Sleeping deeply
25. The medical term for persistently high blood pressure is:
    a) Hypotension
    b) Tachycardia
    c) Anaemia
    d) Hypertension

APPENDIX II

MARKING SCHEME FOR THE BAT PRETEST

1. b)	10. b)	19. b)
2. c)	11. c)	20. c)
3. d)	12. b)	21. a)
4. b)	13. a)	22. c)
5. b)	14. d)	23. d)
6. b)	15. c)	24. b)
7. a)	16. c)	25. d)
8. c)	17. b)	
9. b)	18. b)	

APPENDIX III

WINNEBA SENIOR HIGH SCHOOL

BIOLOGY ACHIEVEMENT POST-TEST (BAT)

SECTION A: Bio-data

Name: ……………………………………………………………………………………

Class: ………………………………… Date: …………………………………..

Instructions: Answer all questions. Choose the single best option.

1. Hereditary spherocytosis patients demonstrate red blood cell abnormalities through which specific change?
   a) Decreased surface-to-volume ratio
   b) Increased haemoglobin F percentage
   c) Abnormal spectrum protein structure
   d) Elevated 2,3-BPG concentration
2. The hepatic portal vein performs a distinctive function by…
   a) Transporting nutrient-rich blood toward the liver
   b) Avoiding pulmonary circulation
   c) Keeping systemic blood pressure stable
   d) Removing cellular waste
3. The leukocyte type which leads the defence against parasitic infections is…
   a) Neutrophils
   b) Eosinophils
   c) Basophils
   d) Lymphocytes
4. The postnatal closure of the foramen ovalis develops into which specific cardiac structure?
   a) Fossa ovalis
   b) Ligamentum arteriosum
   c) Coronary sinus
   d) Moderator band
5. Which functional difference shows the greatest importance when evaluating arterioles in comparison with venules?
   a) Arterioles regulate vascular resistance
   b) Venules contain valves for flow direction
   c) Arterioles have thicker adventitial layers
   d) Venules participate in gas exchange
6. Megakaryocytes function to generate which specific blood component?
   a) Erythropoietin
   b) Thrombopoietin
   c) Platelets
   d) Fibrinogen

7. Which specific heart chamber demonstrates the most substantial thickness in its myocardial wall?
   a) Right atrium
   b) Left atrium
   c) Right ventricle
   d) Left ventricle
8. The dicrotic notch on an arterial pressure waveform corresponds to:
   a) Atrial systole
   b) Aortic valve closure
   c) Ventricular ejection
   d) Coronary perfusion
9. The oxygen dissociation curve of haemoglobin experiences a rightward shift because of...
   a) Increases in pH levels
   b) Lower temperature conditions
   c) High levels of 2,3-BPG
   d) Reduced levels of CO_2
10. Among all vascular beds which one does not have standard capillary architecture?
    a) Renal glomerulus
    b) Hepatic sinusoids
    c) Cerebral microcirculation
    d) Pulmonary alveoli
11. The bundle of His send's electrical signals straight to…….
    a) SA node
    b) AV node
    c) Purkinje fibres
    d) Right bundle branch
12. Patients who have von Willebrand disease would experience problems with…...
    a) Intrinsic pathway activation
    b) Platelet adhesion
    c) Fibrin polymerization
    d) Vitamin K metabolism
13. The majority of blood volume exists within………..
    a) Arteries
    b) Capillaries
    c) Veins
    d) Heart chambers
14. The plasma protein which plays the most important role in maintaining colloidal osmotic pressure is?
    a) Immunoglobulin G
    b) Fibrinogen
    c) Albumin
    d) Transferrin
15. The chordae tendineae stop…….
    a) Atrial overdistension
    b) Ventricular backflow
    c) Valve prolapses
    d) Septal rupture
16. The first erythrocyte index to change during iron-deficiency anaemia is which of the following?
    a) Mean corpuscular volume (MCV)
    b) Mean corpuscular haemoglobin (MCH)
    c) Red cell distribution width (RDW)
    d) Reticulocyte count
17. The coronary sinus empties its blood into which part of the heart?
    a) Left atrium
    b) Right atrium
    c) Left ventricle
    d) Right ventricle
18. Which vascular layer contains vasa vasorum?
    a) Tunica intima
    b) unica media

c) Tunica adventitia
d) Basement membrane

19. A patient with polycythaemia vera would most likely exhibit….
    a) Elevated erythropoietin levels
    b) JAK2 mutation
    c) Microcytic RBCs
    d) Splenic atrophy
20. The moderator band is found in which heart chamber?
    a) Right atrium
    b) Left atrium
    c) Right ventricle
    d) Left ventricle
21. A 50-year-old teacher with a high-salt diet and stress complains of severe headaches and blurred vision. BP reads 180/110 mmHg. What is the immediate concern?
    a) Hypertensive crisis
    b) Migraine
    c) Common cold
    d) Food poisoning
22. A patient with chest pain and ECG showing ST elevation is given aspirin. What condition is being treated?
    a) Heart attack
    b) Indigestion
    c) Anxiety attack
    d) Lung
23. A sickle cell patient develops sudden severe pain and shortness of breath. What complication is likely?
    a) Sickle cell crisis
    b) Malaria
    c) Diabetes
    d) Hypertension
24. A pregnant woman develops swollen ankles and high blood pressure. What condition requires monitoring?
    a) Pre-eclampsia
    b) Anaemia
    c) Varicose veins
    d) Heartburn
25. A patient with atherosclerosis experiences leg pain while walking that disappears at rest. What is this called?
    a) Intermittent claudication
    b) Muscle strain
    c) Arthritis
    d) Nerve damage

APPENDIX IV

MARKING SCHEME FOR THE BAT PROST-TEST

1. a)
2. a)
3. b)
4. a)
5. a)
6. c)
7. d)
8. b)
9. c
10. b)
11. c)
12. b)
13. c)
14. c)
15. c)
16. c)
17. b)
18. c)
19. b)
20. c)
21. a)
22. a)
23. a)
24. a)
25. a)

APPENDIX V

STUDENT PERCEPTION QUESTIONNAIRE (SPQ)

This research instrument bearer holds the status of Master of Philosophy (MPhil) student within the Department of Science Education at University of Education Winneba. This research investigates how inquiry-based learning affects students' results in selected biology topics. The research evaluates how IBL affects academic results alongside gender disparities and student feedback regarding biology education. The questionnaire items are constructed to measure the following:

1. The questionnaire evaluates your biological experiences with Inquiry-Based Learning (IBL).
2. The questionnaire evaluates your biological experiences with Inquiry-Based Learning (IBL).
3. Your perceptions of IBL's effectiveness compared to traditional methods.

Your responses will remain anonymous and used solely for academic purposes. No identifying information will be disclosed in the final research report. The research requires your voluntary involvement together with genuine responses to help improve science education in Ghana. This research study appreciates your valuable participation.

GENERAL INFORMATION

Read the following questions carefully and tick the appropriate response for each question.

Please tick (√) in the appropriate bracket

PART 1: DEMOGRAPHIC DATA

1. Gender: 1. Male [ ]   2. Female [ ]
2. Age 1. 15-16 [ ]   2. 17-18 [ ]   3. More than 18 [ ]
3. Read carefully the following statements and rate them as: ***SD-Strongly Disagree, D- Disagree, N-Neutral, A-Agree, SA-Strongly Agree***

Questionnaire on Students' Perceptions of Inquiry-Based Learning (IBL)

S/no	**Test item**	**SD**	**DA**	**N**	**A**	**SA**
1	IBL made the lessons more interesting and interactive.					
2	IBL helped me better understand complex biological concepts					
3	I felt more engaged in the learning process with the IBL approach.					
4	IBL encouraged me to think critically about the material.					
5	The hands-on experiments in IBL enhanced my learning experience.					
6	I found it easier to apply what I learned in real-world contexts.					
7	IBL helped improve my problem-solving skills in biology.					
8	Collaborating with peers during IBL activities was beneficial for me.					
9	I felt more confident in my understanding of biology after using IBL					
10	IBL made learning biology more enjoyable for me.					

APPENDIX VI

LESSON PLAN FOR EXPERIMENTAL GROUP (IBL)

Lesson 1

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Components of the Circulatory System

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end of the lesson, students will be able to:

3. *Identify the main components of the circulatory system. That is:*
    - *Blood*
    - *Heart*
    - *Blood vessels*
4. *Describe the main components of the circulatory system*

Materials: *The teacher provides students with videos, diagrams, and other resources that explain the key concepts and help students to understand circulatory system better. Stopwatch/timer, electronic blood pressure monitor, graph paper to determine the heart rate at rest and during an activity.*

Engagement (10 mins)

- Teacher introduced stimulating question to during the lesson
    - ➢ *What makes your heart speed up when you are in motion?*
- Teacher presented a brief video which shows a beating heart.
- Teacher instructed students to place their hands on their chest and observe their heartbeat.

- The Teacher then asked students the following questions:
    - What is the function of the heart?
    - What would happen if the heart stopped functioning?
- The students wrote down 2-3 questions regarding the circulatory system through their inquiry process.

Explore (15 mins)

Inquiry Activity: Measuring Heart Rate Before and After Exercise

Teacher asked students:

- Does physical activity affect heart rate?
- Why or why not?

Teacher tasked students to predict what happened in both situations.

Procedure

- Students measured their resting heart rate by counting their pulse 15 seconds and multiplying by 4.
- Teacher guided students to perform light physical activity (e.g., jumping jacks 30 seconds).
- Measure heart rate immediately after exercise.
- Rest 2 minutes and measure heart rate again.

Analysis

- Students recorded their heart rates before and after exercise using the electronic blood pressure monitor.
- Students plotted their data on simple line graph.

Discussion (15 mins)

- Teacher guided students to analyze findings:
    - *What happened to the heart rate after exercise?*

- *Why do you think the heart beats faster during physical activity?*

- Teacher introduced the key components of the circulatory system (heart, blood vessels, blood).
- Teacher uses real-life analogy: Compare the circulatory system to highway system where blood transports oxygen and nutrients like cars delivering goods.
- Teacher answered student-generated questions from the ***Engage phase***

Group Activity (10 mins)

Teacher guided students to undertake the following activities:

- Mini-research with short article excerpts.

Design a poster or infographic on circulatory system health.

Evaluation (10 mins)

To demonstrate the understanding of circulatory system by students, teacher evaluated students by asking them the following questions?

- Why does heart rate increase during exercise?
- Explain how blood moves through the circulatory system.

Self-Assessment

Students evaluated their learning outcomes while tracking which questions, they resolved from the beginning of the lesson.

Lesson 2

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Composition and functions of Blood

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end, students will:

1. Identify the four components of blood (plasma, RBCs, WBCs, platelets).
2. Model how each component contributes to homeostasis.
3. Relate blood disorders to real-world health scenarios.

Materials:

- Microscope slides (blood smears), corn syrup (plasma), red/white beads (cells), clay (platelets).
- Case study cards (sickle cell anemia, leukemia).

Procedure:

Engage (10 mins)

Teacher engages students in the following activities.

- Show a vial of "fake blood" (corn syrup + red/white beads + clay chunks).
- Teacher poses question to students: *"Why is blood thicker than water? What do the different parts do?"*
- Students brainstorm 2–3 questions (e.g., *Why do bruises change color?*).

Explore (15 mins)

- Lab Station 1: Observe blood smears under microscopes (identify RBCs/WBCs).
- Lab Station 2: Simulate blood clotting (mix clay "platelets" with syrup "plasma").

Explain (15 mins)

Teacher summarizes lesson.

Elaborate (10 mins)

Groups research a blood disorder (e.g., sickle cell) and present findings.

Evaluate (10 mins)

- Exit Ticket: *"Which component would increase during an infection?"*
- Self-Assessment: Students label a blood diagram and describe each part's role.

Lesson 3

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Structure and Function of the Heart

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end, students will be able to:

1. Label the chambers and valves of the heart.
2. Trace the path of blood through the heart.
3. Explain how heart sounds relate to valve function.

Materials:

- Sheep/heart model (or 3D diagram), stethoscopes, straws, red/blue yarn.

Procedure:

Engage (10 mins)

- Play audio of a heartbeat.
- Question: *What causes those sounds? Why does the heart need valve?*

- Students predict how blood flows through the heart.

Explore (15 mins)

- Activity 1: Dissect a heart model (identify chambers, valves, vessels).
- Activity 2: Use yarn to map blood flow (red = oxygenated, blue = deoxygenated).

Explain (15 mins)

Teacher demonstrates:

- Pathway: Body → RA → RV → Lungs → LA → LV → Body.
- Valves: Prevent backflow ("lub" = AV valves close; "DUB" = semilunar valves close).

Elaborate (10 mins)

- Case Study: Compare a healthy vs. leaky valve (e.g., murmurs).

Evaluate (10 mins)

- Diagram Quiz: Label heart parts and trace blood flow.
- Reflection: *"How might a blocked coronary artery affect the heart?"*

Lesson 4

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Blood Vessels

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end, students will:

1. Compare arteries, veins, and capillaries.
2. Investigate how vessel structure relates to function.
3. Design a model to demonstrate blood pressure changes.

Materials:

- Rubber tubes (arteries/veins), thin plastic bags (capillaries), water pumps, food dye.

Procedure:

Engage (10 mins)

- Show images of varicose veins and a pulse point.
- Question: *"Why are arteries deeper than veins? Why do capillaries look like webs?"*

Explore (15 mins)

Teacher guides students to experiment:

- Use tubes to model arteries (thick/high pressure) vs. veins (thin/valves).
- Squeeze "capillaries" (plastic bags) to show nutrient exchange.

Explain (15 mins)

Teacher guides learners to contrasts vessels as:

- Arteries: Thick muscle, high pressure. Capillaries: Thin, for diffusion.
- Veins: Valves, low pressure.

Elaborate (10 mins)

Build a vessel system to transport "blood" (dyed water) without leaks.

Evaluate (10 mins)

- Table Quiz: Compare artery/vein/capillary features.
- Real-World Link: *How does smoking affect blood vessels?*

APPENDIX VII

LESSON PLAN FOR CONTROL GROUP (TTM)

Lesson 1

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Components of the Circulatory System

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

- Students will define the circulatory system
- Identify its three main components as blood, heart and blood vessels.

Procedure & Introduction

Teacher introduces lesson by relating topic with movement of drink through a straw sipped by an individual.

writes the term "Circulatory System" on the board and asks students to recall prior knowledge.

Definition: "A transport system of blood, nutrients, and gases powered by the heart."

Lesson development

Teacher guide s students to define the circulatory system.

Teacher then discusses with students the components of the circulatory system as blood, heart and blood vessel.

Teachers draws and labels the circulatory system flow chart

Students listens to teacher explanation and ask questions.

Students write down note as teacher explains the concept.

Conclusion

Learners recall the concept of circulatory system by answering the following questions.

1. What is circulatory system?
2. Outline the components of the circulatory system?
3. Which vessel carries oxygenated blood

Lesson 2

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Composition and functions of Blood

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end, students will:

4. Identify the four components of blood (plasma, RBCs, WBCs, platelets).
5. Model how each component contributes to homeostasis.

Introduction

Teacher introduces lesson by using questioning and answering based on previous lesson.

Lesson development

Teacher guides students to state the components of blood as blood cell and blood plasma.

Teacher discusses how the components of blood composition contributes to homeostasis.

Teacher then projects microscope images of blood smears.

Students copy out notes while teacher discusses lesson.

Closure

Teacher then closes lesson using questioning and answer tags.

Lesson 3

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Structure and Function of the Heart

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end, students will be able to:

4. Label the chambers and valves of the heart.
5. Trace the path of blood through the heart.

Introduction & Development

Teacher revises previous lesson with students.

Teacher guides leaners to copy and label heart diagrams from textbook.

Teacher assists students on how to use stethoscope

Using student’s textbook, students memorize the pathway as

Body → RA → RV → Lungs → LA → LV → Body

Closure

Teacher closes lessons by asking the following questions:

1. Which chamber pumps blood to the lungs?
2. What valve separates LA and LV?

Lesson 4

Subject: Biology

Lesson Title: The Circulatory System

Subtopic: Blood Vessels

Class: SHS 2

Duration: 60 minutes

Lesson Objectives

By the end, students will:

4. Compare arteries, veins, and capillaries.
5. Investigate how vessel structure relates to function.

Lesson development

Teacher revises with students on previous lesson

Teacher explains to students the various blood vessels

Students read from their textbooks in response to the teacher's explanation

Students copy the note from the markerboard into their note books

Closure & Assessment

Teacher closes lesson by posing the following questions to learners

1. The blood vessels are made of how many components?
2. Describe the structure of each vessel?
3. Why do veins have valves but arteries don't?