UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF PROBLEM-BASED LEARNING ON STUDENTS' ACQUISITION OF SCIENCE PROCESS SKILLS AND ACADEMIC PERFORMANCE IN ELECTRICAL ENERGY AND ELECTRONICS IN INTEGRATED SCIENCE

GODKNOWS TORGBEDZU

MASTER OF PHILOSOPHY

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GODKNOWS TORGBEDZU

(8241180015)

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DECLARATION

STUDENT'S DECLARATION

I, GODKNOWS TORGBEDZU, hereby declare that this thesis, with the exception of quotations and references contained in the published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE………………………………...

DATE: ……………………………………….

SUPERVISOR'S DECLARATION

I hereby declare that I supervised the preparation of the thesis in accordance with the rules and regulations of the University of Education, Winneba.

NAME OF SUPERVISOR: DR. NELLY ADJOA SAKYI-HAGAN

SIGNATURE: ....

DATE: ....

DEDICATION

This work is dedicated to my beloved mother, Florence Mama Dogah

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I am especially thankful to my supervisor, Dr. Nelly Adjoa Sakyi-Hagan, whose patience, wise counsel, and constructive feedback shaped this study from the very beginning to its completion. Her mentorship has been both an academic and personal blessing, and I will always remain grateful.

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ABSTRACT

This study investigated the effect of Problem-Based Learning (PBL) on students' Science Process Skills (SPS) and academic performance in Electrical Energy and Electronics in Integrated Science at the senior high school level in the South Dayi District. The study employed quasi-experimental pre-test and post-test design involving experimental and control groups. Two intact second-year classes of ninety-five (95) students from Peki Senior High School and Peki Senior High Technical School were purposively sampled. The experimental group was taught using PBL while the control group was taught using the traditional lecture method. The instruments used for data collection were Students' Science Achievement Test (SSAT), Science Process Skills Achievement Test (SPSAT), questionnaire, interview guide, and an observation checklist. Statistical Package Foe Social Sciences (SPSS) was used to analyse data. The findings showed that PBL significantly improved students' acquisition of SPS, with steady gains recorded in observation, measurement, inferring, predicting, and classifying. Academic performance also improved, with the experimental group outperforming the control group ($t = 6.38$, $p = 0.00$). Gender analysis revealed no significant differences ($p = 0.43$), indicating that PBL benefits both male and female students equally. Students' perceptions of PBL were overwhelmingly positive, noting improvements in understanding, motivation, research skills, and teamwork. The study concludes that PBL enhances academic performance, fosters SPS development, and promotes learner engagement, making it a relevant and inclusive pedagogy for electrical energy and electronics Integrated Science. It is recommended that PBL should be employed in teaching Electrical Energy and Electronics in Integrated Science.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter presents the background to the study, the statement of the problem, and the purpose of the study. The structure of the chapter also includes the specific objectives, research questions, hypothesis and significance of the study. It also contains the limitations, delimitation and organisation of the study.

1.1 Background to the study

It is globally acknowledged that a nation's development efforts depend heavily on the advancement and use of science and technology (Daraojimba et al., 2023). Science education is needed in Ghana to produce the necessary human resources and skilled labour force to manage our local industries (Ozor et al., 2024). According to Guerrero and Sjöström (2024) and Taber (2017), science education provides the individual with basic scientific knowledge about science concepts such as matter, energy, ecosystem, and the scientific process. Osborne (2023) also asserted that the central purpose of science education is still regarded as scientific literacy.

Recent studies also show that science education in pre-tertiary institutions provides a conceptual framework where an individual could understand the average issues of science involving health and nutrition (Doustmohammadian et al., 2022), technology and the environment (Vishal et al., 2024). Recent studies have revealed that countries with high levels of science education manage to produce a population that literate, fostering innovation and technological advancement (Valladares, 2021; Zafer & Hilal 2023).

Integrated science is a compulsory subject in the pre-tertiary educational curriculum in Ghana (National Council for Curriculum and Assessment, NaCCA, 2019; Ministry of Education, MOE, 2019). The Integrated Science curriculum combines physics, chemistry, biology and agriculture into a single course to ensure that students appreciate the interrelationship that exists between the various branches of science (Mnguni, 2021; Quansah et al., 2019). Being one of the most important subjects for all students in pre-tertiary schools in Ghana, it forms an integral part of the country's educational system towards developing scientifically literate citizens (Mensah, 2016; MOE, 2019). It also enables students to have a deeper understanding of scientific concepts and how they can be applied by learning how these disciplines interact in real-life scenarios.

According to Azowenunebi (2019), the physics aspect of the integrated science is the most utilised in most technology and technology-related professions, particularly electrical energy and electronics. This indicates that the important role electrical energy and electronics play in the technological, social and economic development of any nation cannot be underestimated.

For these reasons, the government of Ghana has made integrated science compulsory to equip students with the knowledge and skills necessary for appreciating the natural world and addressing some contemporary societal issues (Annan, 2020; NaCCA, 2019).

Despite this, it appears students' academic performance at the senior high school level with regards to electrical energy and electronics over the years has been below expectations (Azowenunebi, 2019; MOE, 2021; West African Examinations Council, 2020). Electrical energy and electronics are considered a central area of integrated science curricula at primary, junior high and senior high levels of education (NaCCA, 2019).

Additionally, electrical energy and electronics as one of the basic areas and important topics in science have applications covering many aspects of our everyday life (Alves et al., 2025). However, this area has been reported to have several concepts in which students find difficulty and develop views that are different from those accepted scientifically (Mbonyiryivuze et al., 2019). According to MOE (2019), a central aspect of the common core curriculum is the concept of the three integral learning domains that should be the basis for instruction and assessment. These learning domains are knowledge, understanding and application, science process skills, and attitudes and values.

Research indicate that science process skills are critical for understanding and investigating the world around us (Elfeky & Elbyaly, 2023; Rini & Aldila, 2023). According to Ainun and Jefriyanto (2023) and Sarı, et al. (2020), science process skills are skills that involve observing, classifying, comparing, communicating/reporting, predicting, analysing, generating possibilities, evaluating, designing, measuring, interpreting, recording and generalising information. A study conducted by Mulyenı, et al. (2024) also asserted that science process skills are the fundamental skills that support all scientific research and students apply each scientific process skill in a variety of situations throughout their lives. The acquisition of these skills provides bases for lifelong learning, preparing students for careers in science and technology, thereby creating citizens with the requisite scientific knowledge to solve problems (Juhji & Nuangchalerm, 2020; Okada et al., 2024; Safaah et al., 2017).

Furthermore, the development of these skills in senior high school students hinges on the instructional methods that science teachers adopt during the teaching and learning process (Juhji & Nuangchalerm, 2020; Safaah et al., 2017). In recent time, curriculum developers and stakeholders in Ghana are emphasising the use of learner-centred teaching approaches such as problem-based learning (PBL) as indicated by the common core curriculum (Boye & Agyei, 2024).

Problem-based learning (PBL) is a teaching approach in which students use real-world situations that are connected to their curriculum content to solve a problem. Senisum et al. (2022) opined that problem-based learning (PBL) is an instructional approach where students solve real-world problems related to learning materials. This approach provides students with more control over their learning while teachers serve as facilitators for the teaching and learning process. As students are engaged in inquiry and self-directed learning, they construct their own knowledge during the various stages of problem-based learning processes (Duha & Kaur, 2023).

Additionally, problem-based learning provides students with the opportunity to work with their peers and resolve their divergent points of view during the learning process. This process enhances students' collaborative and communication skills as well as improves their understanding of the subject (Boye & Agyei, 2023). Research also indicates that problem-based learning has the potential to improve learning outcomes and critical thinking if it is properly implemented (Jumhur et al., 2024).

Zhang and Ma (2023) analysed 66 studies over 20 years, finding that PBL significantly enhances learning outcomes, particularly in academic achievement, affective attitudes, and thinking skills, compared to traditional methods. The study highlighted that PBL's impact is strongest in Southeast Asia, exceeding its effectiveness in Western Europe and North America. Additionally, PBL is especially effective in STEM subjects, such as engineering and technology, where hands-on, lab-based learning fosters deeper understanding and application of concepts (Zhang & Ma, 2023).

According to Deutscher et al. (2021), PBL curriculum boosted student achievement across multiple subjects. Science scores improved, students using the Learning Through Performance (LTP) curriculum also outperformed their peers on state assessments in mathematics and science. Additionally, English language learners showed notable improvements in language proficiency, especially when taught by teachers with more experience using the LTP curriculum. Student engagement also increased with the PBL approach (Deutscher, et al., 2021). A study by Duke et al. (2020) also revealed that PBL curriculum led to gains in social studies and informational reading.

Research suggests that PBL positively affects both male and female students, but the degree of improvement may vary. There is some evidence to indicate that female students perform better in PBL environments since they possess superior collaborative and communication skills, (Borgonovi et al., 2023; Zhu, 2007) while male students excel in individual problem-solving activities (Yusuf, 2023; Dew et al., 2023).

In physics and engineering-related SPS, males may show higher proficiency in manipulating lab equipment and conducting hands-on experiments, whereas females may outperform in data interpretation and written analysis. In biology and chemistry, female students tend to perform equally or better than males, especially in theoretical and conceptual areas (Tsaousis & Alghamdi, 2022). However, other research presents contrasting findings. An analysis of academic performance across multiple introductory biology classes revealed that female students consistently underperformed in exams compared to male students with similar overall college grade point averages (Cotner et al., 2014). In physics and mathematics, male students often outperform females, particularly in problem-solving and spatial reasoning tasks. Male students outperformed female students on both spatial ability tests, indicating a significant gender difference in spatial skills (Ramírez & Ramírez-Uclés, 2020).

Despite these studies, no research has been conducted to assess the effect of problem-based learning on students' academic performance, science process skills and gender differences in learning outcomes in electrical energy and electronics.

1.2 Statement of the Problem

In Ghana, the Senior High School Integrated Science curriculum emphasises the use of activity-based teaching approaches to guide students' science process skills development as well as improve their academic performance (Azumah & Najah, 2024). In order to achieve this, the ministry of education has allocated a total of five periods a week, each consisting of forty minutes, to the teaching of Integrated Science at the senior high school level. Two out of these five periods are designated for practical works. However, the teaching and learning of Integrated Science in most senior high schools generally appears to be teacher-centred, where the teacher talks, perform chalkboard illustrations while students observe and write notes (Azuuga et al., 2021). In Peki senior high school, where the researcher teaches, the situation is not different. A reconnaissance survey conducted by the researcher in Kpeve Senior High Technical School and Peki Senior High Technical

School showed that the problem is widespread (Peki SHS, 2022; Peki SHTS, 2023; Kpeve SHTS, 2023). The researcher's observation revealed that most Integrated Science teachers adopt the lecture method in lesson delivery. This may have resulted in poor acquisition of science process skills and low performance in Integrated Science among the students. Majority of the students have no interest in Integrated Science because they cannot connect with what their teachers teach (Peki SHS, 2022).

The researcher's experience and encounter with students further revealed that most of them are substituting Integrated Science for Social Studies in order to pass three compulsory subjects as a requirement for admission to tertiary institutions. This is evident in the continuous low performance of students in Integrated Science Examination conducted by the West Africa Examinations Council over the years. In the past three years, no senior high school within the North Dayi District has recorded percentage pass higher than 50% (Peki SHS, 2022; Peki SHTS, 2023; Kpeve SHTS, 2023).

Although several studies have been conducted on problem-based learning (Boye & Agyei, 2023; Choirunnisa et al., 2018; Kasuga et al., 2022; Utomo & Sayekti, 2022), no studies have been conducted on the effects of PBL on students' academic performance and science process skills in Electrical Energy and Electronics in Integrated Science. The study seeks to examine the effect of PBL on the acquisition of science process skills such as observing, classifying, measuring, predicting, and inferring as well as students' academic performance in electrical energy and electronics.

1.3 Purpose of the study

The purpose of the study was to investigate the effect of problem-based learning on students' acquisition of science process skills and academic performance in electrical energy and electronics in integrated science.

1.4 Objectives of the study

The objectives of the study were to**:**

1. Determine the influence of problem-based learning on students' acquisition of science process skills in the study of electrical energy and electronics in integrated science.
2. Determine the extent to which problem-based learning affects students' academic performance in the study of electrical energy and electronics in integrated science.
3. Assess the difference between females and males in their academic performance in the study of electrical energy and electronics in integrated science.
4. Investigate the perceptions of students on the use of problem-based learning in the study of electrical energy and electronics in integrated science lessons.

1.5 Research questions

The study was guided by the following questions**:**

1. What is the influence of problem-based learning on students' acquisition of science process skills in the study of electrical energy and electronics in integrated science?

2. What is the impact of problem-based learning on students' academic performance in electrical energy and electronics in integrated science?
3. What are the gender differentials in students' acquisition of science process skills electrical energy and electronics in integrated science lessons?
4. What are the perceptions of students on the use of problem-based learning in the study of electrical energy and electronics in integrated science lessons?

1.6 Null Hypothesis

H_1: There is no statistically significant effect of problem-based learning on the acquisition of some selected process skills among students in Electrical Energy and Electronics in integrated science.

H_2: There is no statistically significant effect of problem-based learning on academic performance of students in electrical energy and electronics in integrated science.

H_3: There is no significant difference in academic performance between female and male students in the study of electrical energy and electronics in Integrated Science.

1.7 Significance of the Study

This research will serve as a source of information to help create awareness in integrated science teachers on the effect of problem-based learning approach compared with the traditional methods of teaching in Senior high School students' acquisition of science process skills. This research will also help participants develop positive attitude towards the study of integrated science by providing a more supportive and less intimidating science classroom environment for learning. It would also provide an insight into the effect of PBL on SHS students 'perception towards learning of Integrated Science, specifically electrical energy and electronics in the study area. This research will contribute to the broader field of educational research by adding to already existing knowledge on problem-based learning, academic performance and the development of science process skills. This will strengthen the connections between research, policy, and classroom practice. It would also serve as basis for further research work on problem-based learning, science process skills and integrated science in pre-tertiary institutions by highlighting areas where further studies are needed.

1.8 Delimitations of the Study

The study was delimited to only Peki Senior High School and Peki Senior High Technical school in the South Dayi district of the Volta Region. Only two classes were used for the study. It was also delimited to only form two students. The study was further delimited to two topics in integrated science, focusing on electrical energy and electronics in the SHS integrated science syllabus. Additionally, the study was delimited to two teaching strategies, i.e. problem-based learning and lecture method. The duration for the intervention was limited to 6 weeks.

1.9 Limitations of the Study

Extraneous variables such as students' previous learning experience, age, maturation and ability were beyond the control of the researcher. These variables may influence the science process skills and academic performance of the study population. Timeframe within which the study was conducted was relatively short.

1.10 Organisation of the Study

The study was organised into five chapters. Chapter one presented background to the study, statement of the problem and purpose of the study. It also displayed objectives of the study, research questions null hypothesis significance of the study delimitations of the study and limitations of the study. Chapter two presented a review of related literature relevant to the study. This included theoretical and conceptual frameworks. Chapter three highlighted the methods that was appropriate for the study. These methods include the research design, study variables, location of study, target population, sampling techniques, construction of research instruments, validity and reliability of data, and data collection techniques. The results and discussions of research findings was presented in chapter four. Chapter five contained a summary of the study, conclusion, and recommendation. Implication of findings and suggestion for additional research.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

This chapter discusses the review of existing literature related to the study. Literature was collected from various sources that are intimately linked to the study's theme and purpose. This chapter presents various concepts used in the research and further explains the theories that provide bases for the study. Thematic areas covered include: theoretical framework, conceptual framework of the study, empirical review of related studies, scope of the SHS integrated science syllabus, importance of teaching methods in integrated science, the concept of problem-based learning in science, goals of problem-based learning, features of problem-based learning, the relevance of problem-based learning in the science, students' science process skills in integrated science, students' academic performance in integrated science, teaching and learning of electrical energy and electronics in senior high school in Ghana, gender and student' achievement in science, Students' perceptions on the teaching methods use in Integrated Science.

2.1 Theoretical Framework of the study

The theoretical framework that underpins this study is social constructivism by Vygosky,1978. Social constructivism emphasises that learning is based on adaptable problem solving in real life, which occurs in a social setting through sharing of experiences and interaction with others. Through social constructivism, learners compare new ideas to their previous knowledge, and adjust rules to make sense of the world (McMahon, 1997).

Social constructivism guides this study by viewing learning as an active and social process where students build knowledge through interaction, collaboration, and problem solving (Vygotsky, 1978). This connects directly to the use of Problem-Based Learning (PBL) in Integrated Science, especially in Electrical Energy and Electronics, where students must go beyond memorising formulas to applying ideas in practical situations. The approach also supports the growth of key Science Process Skills (SPS) such as observation, classification, measurement, inference, and predicting. These skills develop best when learners work together on real problems, share their views, and receive guidance from teachers and peers. PBL brings this theory to life by making students active problem solvers while teachers act as facilitators. This is highly suitable for electrical energy and electronics in Integrated Science, which requires not just theory but application in experiments and real-world contexts. Social constructivism provides a strong foundation for this study, showing how SPS and academic performance improve when students learn actively, collaborate with peers, and tackle meaningful problems.

2.2 Conceptual Framework of the Study

A Conceptual Framework is a framework in which concepts, ideas, and variables are related to each other for a better understanding of the phenomenon or problem being addressed. It describes how consistent and logical thoughts, ideas, and research findings are systematically organised (Siddaway, et al., 2019).

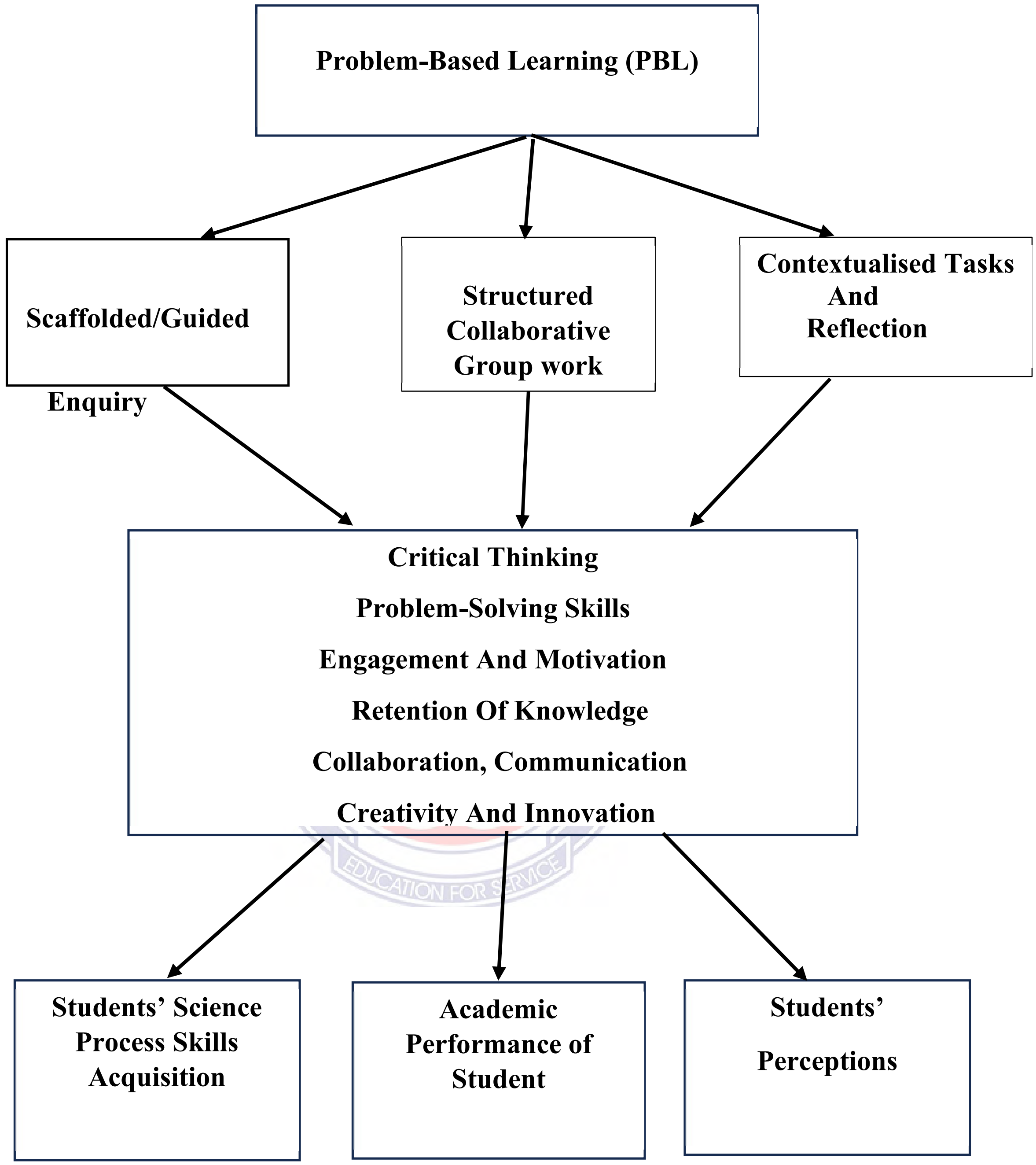

Figure 1. Conceptual Framework of problem-based learning

Source: Author's construct, (2025)

2.3 The scope of the Ghana Education Service Senior high school integrated science syllabus

The integrated science syllabus for senior high school forms part of the Ghanaian education system and it was designed to enhance scientific literacy, critical thinking, and problem-solving among students (Bardoe et al., 2023). It combines fundamental ideas from biology, chemistry, physics, agriculture and environmental science which prepares students not only for higher education but also for active participation in national development (MOE, 2010). For this reason, the Integrated Science syllabus has aimed at connecting abstract knowledge with practical life, particularly in areas such as health, agriculture, technology, and the environment. The senior high school syllabus for integrated science consists of topics which covers a broad range of topics from biology, chemistry, physics, agriculture and environmental science. Each of these subjects is taught in a way that shows how they are connected, to ensure that students get a broader and deeper understanding of science as a whole. For example, the biology part of the syllabus covers diversity of living things, human anatomy, genetics and ecology, the chemistry part covers atomic structure, chemical bonding and reactions (MOE, 2010; Bardoe et al., 2023). The physics part entails force, motion and pressure, light energy, mechanics, electricity, magnetism and thermodynamics with practical applications like energy conservation and use of simple machines. The agriculture aspect of the syllabus details farming system, animal production and crop production, Environmental science is also integrated into the syllabus to promote awareness of sustainable practices and the impact of human activities on ecosystems.

One of the main aims of the syllabus is to develop scientific inquiry skills among students for them to be able to conduct experiments, analyse data and apply scientific methods to real life problems. The practical component is essential to achieving this goal, and the syllabus requires that students spend time in laboratories or engage in fieldwork to reinforce theoretical knowledge. This approach aligns with global trends in science education, which emphasise hands-on learning and problem-solving as critical to developing scientific competence (Boampong et al., 2016).

2.4.1 The Concept of Problem -Based Learning in Science

Globally, the educational system has recognised Problem-Based Learning (PBL) as an effective teaching strategy that strives to improve students' critical thinking, problem-solving, and practical knowledge applications. Actually, the reason PBL is so important in science education is because it mirrors the steps involved in scientific inquiry: real-world issues (Chistyakov et al., 2023), solution experimentation, and teamwork to find answers (Lakha, 2025). PBL offers the chance to switch from the conventional rote learning technique to student-centred approaches that foster deeper understanding and skill acquisition in Ghana, where scientific knowledge is extremely important to the country's growth.

PBL's central feature is the use of complex, problems that stimulate students' inquiry. These problems are designed to replicate real-world challenges, demanding that students engage with multiple perspectives. According to Strobel and van Barneveld (2009), the complexity of the problems presented in PBL environments encourages students to apply critical thinking and decision-making skills. Ferreira and Trudel, (2012) and Kwon and Lee (2025) both argue that these complex problems reflect the challenges faced in scientific research, where answers are seldom straightforward and often require deep investigation and creativity.

Similarly, Beem et al. (2023) and Okyere et al. (2023) highlighted the success of PBL in motivating students by exposing them to real-life science-related problems such as environmental degradation and sustainable farming. This increased students' engagement and led to higher retention of scientific concepts.

Another key component of PBL is self-directed learning. Learners are to take responsibility for determining what they do not know and need to learn in order to solve a problem. Evidence supports the idea that PBL promotes lifelong learning skills, especially in the field of science education, where constant new developments demand adaptability (Asyhari et al. 2023).

There is evidence that PBL promotes independence and leads to a deeper understanding of scientific inquiry. For example, according to Sabariah (2025), learners who undertake PBL tend to show more initiative in learning in the process of developing problem-solving skills. Hybrid teaching using PBL improved students' capacity for self-directed learning, as Chen et al, (2024) found. This confirms what Strobel and Van Barneveld (2009) discovered that students manifest higher autonomy in a PBL classroom in order to increase their engaging and overall learning process.

Collaboration is critical in PBL, where students work in teams to solve problems. According to Walker et al. (2018), collaboration in PBL mirrors the collaborative nature of scientific research, requiring students to share knowledge, challenge each other’s ideas, and develop solutions collectively. Sanatbay et al. (2025) supported this, noting that students develop communication, negotiation, and leadership skills through PBL group work.

In a review of Ghanaian studies, Okyere et al. (2023) and Asanre et al., (2024) found that group work in PBL improved not only students' academic performance but also their interpersonal skills, which are essential for future STEM careers. Collaborative PBL helped students from diverse backgrounds share information and learn from each other's experiences, leading to a more inclusive learning environment.

In PBL, the role of the teacher becomes that of a facilitator or guide rather than a source of information. Teachers scaffold and provide feedback to the student as they work their way through the inquiry but never give direct solutions to the problem (Roberts et al., 2022; Saleh et al., 2019).

As a result, this change from a teacher-centered to a learner-centered approach requires proper training for teachers since PBL entails establishing a learning environment in which students feel encouraged yet independent of the teacher. In Ghana, this has elicited challenges as well as opportunities. Okyere et al., (2023) pointed out that some teachers have problems with class control, especially in environments where traditional methods of teaching dominate. Alam (2023) also underscored the need for ongoing professional development to support teachers through the transition from a teacher-centered to a learner-centered approach.

The real-world relevance of PBL is one of its strongest features. Allchin (2017) noted that PBL problems are often modeled after real-world scientific challenges, requiring students to apply theoretical knowledge in practical ways. This practical application helps bridge the gap between classroom learning and real-life science. Study by Gök and Boncukçu, (2023) found that PBL significantly improves the ability of students to view how scientific principles relate to their everyday lives. For instance, students who participated in PBL projects on water conservation and waste management showed a better level of engaging in learning and understanding of environmental science compared to those taught in the traditional way. Similarly, Walker et al. (2018) also found that PBL increased students' motivation and engagement in learning as they could see how their studies could help to address different problems in society.

Reflection is a key component of the PBL cycle, as students are encouraged to evaluate their problem-solving process, learn from their mistakes, and revise their solutions accordingly. According to Lukitasari et al. (2021) and Rengkuan, et al. (2024). this iterative cycle of reflection and revision fosters metacognitive skills, teaching students to think about their own thinking processes and adjust their approaches when necessary.

Okyere et al., (2023) added that this reflective process in PBL allowed Ghanaian students to become more self-aware learners, improving their ability to adapt their strategies and learn from failure. Similarly, a study by Krajcik and Delen (2017) indicated that iterative learning in PBL environments encouraged students to be persistent in the face of complex problems, a skill that is invaluable in scientific research.

Furthermore, PBL encourages interdisciplinary learning, particularly in science, where solutions to problems often require knowledge from various fields. Studies by Strobel & van Barneveld (2009) and Allchin, (2017) showed that PBL encourages students to integrate concepts from biology, chemistry, physics, and environmental science, providing them with a holistic understanding of scientific problems.

2.4.2 Theoretical Foundations of Problem-Based Learning

Problem-Based Learning is based on constructivist theories of education, especially those putting emphasis on learning as an active process of knowledge construction through experience and social interaction. The PBL foundation is built on Piaget's cognitive development theory and Vygotsky's social constructivism where students learn to solve complex, open-ended problems in a collaborative setting (Saleh, et al., 2019). With PBL, students work in groups and try to find a solution to a problem by means of investigation. In such a case, the teacher acts as a facilitator rather than a traditional teacher. Such an approach leads to self-responsibility of learning, increased self-directed inquiry, and development of critical thinking on real-world situations among students (Roberts et al., 2022). In science education, PBL is in line with the scientific method as students are asked to put forward questions, formulate hypotheses, design experiments, and analyze data.

Severance et al. (2025) argue that this approach helps learners develop a deeper understanding of scientific concepts, moving from memorisation to applying knowledge to solve practical problems. This is so, especially within the Ghanaian educational context, where traditional teaching methods have mostly emphasised rote learning at the expense of applied knowledge in real-life contexts (Abugbilla, 2023).

2.4.3 Effect of problem-based learning on students' academic performance in science.

Problem-Based Learning (PBL) has increasingly gained recognition as a transformative educational strategy designed to enhance students' academic performance through active engagement with real-world, problem-solving scenarios. Studies have shown that PBL positively influences student outcomes across many domains, with clear gains found in science education (Liu et al., 2019; Strobel & van Barneveld, 2009).

studies emphasise the effectiveness of PBL in promoting deeper conceptual comprehension, higher-order critical thinking skills, and increased student engagement, ultimately leading to improved academic outcomes (Yew & Goh, 2016).

Strobel and van Barneveld (2009) stated that, compared to traditional instructional strategies, PBL enhances retention of scientific knowledge. They further indicated that those students who had undergone PBL scored higher in terms of their problem-solving skills, critical thinking, and ability to apply scientific concepts in novel situations. These findings are very relevant to the teaching of Integrated Science in Ghana, where there is an expressed desire to improve students' application of theoretical knowledge in practical contexts.

Abugbilla (2023) conducted a study in the Ghanaian secondary school with the aim of assessing students' understanding of biology concepts through PBL. The study revealed that students taught using the PBL in biology lesson actually showed better performance in assessment as compared to those taught using traditional lecture method. The researcher concluded that PBL not only enhances students' understanding of biological concepts but also fosters collaboration and communication skills, which are prerequisites in scientific inquiry.

A study conducted by Merritt et al. (2017) in United States similarly provided evidence from Mathematics and Science education demonstrating that PBL effectively enhances students' abilities to apply theoretical knowledge to novel scientific problems. Their study showed that students engaged in PBL through mathematics and science significantly improved their capacity for integrating and utilizing diverse mathematics and science concepts and processes when confronted with unfamiliar scientific scenarios. This approach promoted cognitive flexibility by enabling students to recognize patterns and connections among different mathematics and science and facilitated knowledge transfer by fostering a deeper understanding that extends beyond rote memorisation, allowing for meaningful application across varied contexts.

In chemistry education, findings by Valdez and Bungihan, (2019) showed that PBL improved students' problem-solving abilities and practical laboratory skills in secondary school chemistry. A study conducted by Liu, et al., (2019) also investigated the use of PBL in chemistry education in the classrooms of Ghanaian SHS. This study also showed that PBL increases students' interest and participation in chemistry, leading to better performances on both practical and theoretical tests. The authors noted that in PBL, students could delve into the chemical concepts in a practical way; hence, deepening their understanding and making learning more enjoyable.

Similarly, the study by Aidoo et al. (2016) demonstrated that PBL encourages students to develop interdisciplinary understanding, enabling them to effectively synthesize and apply scientific concepts across varied domains, resulting in superior academic performance. Gumisirizah et al., (2023) conducted research focusing on secondary physics classrooms and demonstrated that PBL significantly improves students' mastery of core physics concepts, enhances their critical-thinking capabilities, and promotes greater engagement with the subject matter. The study highlighted that students participating in PBL were better able to apply theoretical concepts such as mechanics, thermodynamics, and electromagnetism in practical contexts, reflecting a deeper internalization of knowledge.

In addition, research by Freeman et al., (2014) and Nicholus et al., (2023) reinforced the positive correlation between PBL and improved physics learning outcomes. Their findings suggest that students involved in problem-based instructional approaches demonstrated higher proficiency in applying scientific reasoning, solving complex physics problems, and interpreting experimental data accurately compared to their peers receiving traditional instruction.

Studies also highlights the broader psychological and motivational benefits associated with PBL. Freeman et al., (2014) argue that students engaged in PBL settings frequently exhibit higher intrinsic motivation, enhanced self-confidence, and sustained interest in science education, factors consistently associated with elevated academic performance. Additionally, Walker et al. (2018) and Ssemugenyi (2023), found that the active, student-centered nature of PBL facilitates greater learner autonomy, intrinsic motivation, and deeper cognitive engagement, which are essential for long-term academic success in science education.

Further reinforcing these findings, Sisrayanti et al., (2024) and Hafizah et al. (2024). noted that students participating in PBL contexts often demonstrate improved problem-solving abilities and heightened critical thinking skills, contributing significantly to their academic successes. More recent studies by Taiula et al. (2025) confirmed these observations, highlighting substantial gains in analytical and reflective thinking capacities among students actively involved in PBL methodologies compared to traditional instructional formats.

Moreover, research underscores the crucial role of teacher facilitation and structured instructional support in achieving optimal academic outcomes through PBL. Roberts et al. (2022) argued that successful PBL implementation relies on teachers' ability to scaffold students' learning, manage collaborative group dynamics, and foster environments conducive to inquiry.

2.4.5 The importance of PBL in the Science

PBL has been a very effective teaching method in general and in scientific education specifically because it encourages critical thinking, problem-solving, collaboration, and the practical application of information. PBL's relevance in science education stems from its alignment with 21st-century expectations, which focus on developing the abilities required to solve challenging scientific issues. Numerous studies shown that PBL improved students' ability to apply scientific ideas in realistic contexts while simultaneously improving academic performance (Krajcik & Delen (2017).

One of the significant benefits associated with PBL is that it has the potential to support student engagement, especially in science education. PBL takes students from a passive learner to an active inquirer. According to Strobel and van Barneveld (2009), students in PBL settings report higher levels of engagement compared to traditional classroom settings. The open-ended nature of PBL problems, often based on real-world issues, encourages curiosity and motivation in students by allowing them to see the relevance of what they are learning. Walker et al. (2018) provide supporting evidence for this, where students in PBL science courses showed greater engagement with the material and higher academic performance. Moreover, students expressed greater interest in pursuing careers related to science.

A study conducted by Apeadido et al., (2024) also found that the senior high school students have shown higher enthusiasm and motivation towards science when exposed to PBL. Koomson et al., (2024) further noted that the students showed more willingness to participate in discussions, collaborate with peers, and seek solutions independently, which might be an indication that PBL fosters a more stimulating and inclusive learning environment.

The fundamental idea of PBL is to expose students to challenging, real-world problems. This makes it highly relevant for developing critical thinking and problem-solving skills among students. These skills are particularly important in science education, where students are expected to analyze data, formulate hypotheses, and solve problems in a systematic manner. Glazewski and Hmelo-Silver (2019) also pointed out that PBL enhances students' critical thinking ability, as students have to evaluate different perspectives and consider alternative ways of solving problems.

Barron et al., (2014) supports this finding that PBL consistently improves students' critical thinking abilities across a range of disciplines, including the sciences. Confronting students with unambiguous, open-ended problems, PBL encourages students to evaluate evidence and make informed decisions about that evidence while reflecting on their reasoning. In science, where complex problems often require interdisciplinary approaches, the relevance of PBL is even more pronounced. Similarly, Appiah-Adjei et al. (2025) reported that students in the senior high schools in Ghana who were involved in PBL were better able to apply scientific concepts to real-life problems, such as environmental conservation and health-related challenges. This is evidence that PBL is an effective method in developing critical thinking skills that transcend mere rote memorisation and encourage application in practical contexts.

One of the greatest contributions that PBL has made to science education is bridging the gap between theoretical knowledge and practical application. In traditional classrooms, students are often unable to see how abstract scientific concepts apply to real-world situations. PBL tackles this problem by providing students with real-life problems that require them to apply theoretical knowledge in finding solutions (Saleh et al.,2019).

According to Walker et al., (2018) and Mohd-Yasin, (2024), this practical application of knowledge in PBL settings makes students understand scientific concepts better and learning more meaningful. In a study conducted among secondary school students in Ghana, Okyere et al., (2023) established that PBL significantly improved students' ability to relate classroom learning to real-life scenarios. For instance, in a PBL project on water purification, students could apply knowledge from chemistry and biology to real-life problems and then be led to deeper understanding of the underlying scientific principles.

Similarly, PBL gives students a chance to see science as it is applied in the real world, where most issues are multidisciplinary and require teamwork and creativity to solve (Roberts et al., 2022). Because science is so relevant in today's world, PBL is especially helpful in preparing students for STEM-related employment.

Collaboration is a key feature of PBL, and its relevance in science education is particularly significant given the collaborative nature of scientific research. In PBL, students work in small groups to solve problems, which fosters teamwork, communication, and leadership skills. Ghani et al., (2021) argue that the collaborative aspect of PBL mirrors the way scientists work in research teams, where sharing knowledge and ideas is essential for solving complex problems. Studies have shown that PBL improves students' interpersonal skills, which are often underdeveloped in traditional science classrooms (Hasni et al., 2016; Strobel & van Barneveld, 2009). In Ghana, Appiah-Adjei et al. (2025) found that students who participated in PBL-based science education were better at collaborating with their peers, listening to different perspectives, and communicating their ideas effectively. This collaborative experience is highly relevant for future careers in science where teamwork and communication are critical.

PBL is designed to instill an attitude toward lifelong learning, which is so important in science, since knowledge keeps on changing. According to Glazewski and Hmelo-Silver (2019) PBL encourages students to become independent learners who will be motivated to seek new information, ask questions, and continue learning outside the classroom, an essential attribute in the area of science education, since science requires inquiry and exploration.

Research by Krajcik and Delen (2017) provides more evidence for this, demonstrating how PBL empowers students to take charge of their education and cultivate the abilities required for scientific investigation. Students in a PBL context gain the ability to recognize knowledge gaps, seek solutions, and apply those solutions to difficult tasks through self-directed learning. PBL in Ghana helped students develop a deeper interest in science and inspired them to study outside of the classroom, which is a crucial skill for success in STEM fields (Oduro-Okyireh et al., 2024).

The relevance of PBL in science education is further emphasized by its alignment with the skills needed for success in the 21st century. According to Roberts et al., (2022), PBL helps students develop critical thinking, creativity, collaboration, and communication skills that are essential in a rapidly changing world. In science education, these skills are particularly important, as they enable students to tackle complex problems, work effectively in teams and communicate their findings clearly.

PBL is even more important in science education since it incorporates the abilities that are now necessary for success in the twenty-first century. Roberts et al., (2022) asserts that PBL fosters the development of critical thinking, creativity, teamwork and communication in students. These abilities are especially crucial in science education as they will enable students to effectively tackle challenging issues, collaborate with others, and clearly present their research.

According to Strobel and van Barneveld (2009), PBL continuously enhances students' critical thinking, problem-solving, and teamwork abilities, skills that are highly sought after in the contemporary workforce. According to Amoako-Sakyi and Amonoo-Kuofi

(2015) PBL in Ghana was successful in preparing students for the challenges of the twenty-first century by fostering critical thinking, teamwork, and practical application of information.

2.4.6 Challenges of Implementing Problem-Based Learning in Ghana

Despite the proven benefits of PBL, there are several challenges to its implementation in Ghanaian schools. One of the major barriers is the traditional nature of science teaching in Ghana, which often involves rote learning and teacher-centered approaches (Okyere et al., 2023). Many teachers are accustomed to lecturing and may find it difficult to shift to a more facilitative role in the classroom. Consequently, teacher training is a prerequisite to the effective realization of PBL in schools across Ghana. According to Okyere et al., (2023), professional development programs are needed to provide teachers with both the ability and confidence to correctly realize PBL (Shernoff et al., 2017). The second big hindrance to implementing PBL in most schools in Ghana is the constraint of resources.

Science education normally requires practical equipment and materials, which are in short supply in most schools, especially those in rural areas. For instance, a study by Asare et al. (2022) and Takyi et al., (2019) showed that the inadequacy of laboratory resources in most schools in Ghana has limited teachers' possibilities of carrying out practical, problem-based science lessons with students. The researchers suggested that schools find alternative ways, such as the use of virtual labs or simulation, to overcome these resource constraints. Group dynamics also present challenges in PBL. Walker et al. (2018) criticized that in some PBL settings, student discussions are dominated by brighter students, making the weaker students disengage. This problem is even worse in the in some schools due to large classes and some classroom environments that are said to be hierarchical, where students may be too fearful to tackle their peers or even in open discussions, reveal their thoughts. Okyere et al., (2023) suggested that teachers should be proactive in their approach towards group dynamics and at the same time ensure that all students participate actively in the learning process.

2.5.1 Students' science process skills

Science process skills (SPS) are defined as the cognitive and practical abilities that scientists and learners use to acquire, understand, and communicate scientific knowledge. SPS are bases to the practice of scientific inquiry, enabling students to develop a hands-on, experiential understanding of science rather than simply learning facts. According to Chengere et al., (2025), science process skills are not just tools for professional scientists but are essential for all learners to understand the nature of science and to engage meaningfully with scientific knowledge.

The importance of SPS in science education is widely recognized because they equip students with the ability to approach problems methodically, make observations, collect data, and draw evidence-based conclusions. As noted by Jannah and Wulandari (2025), the mastery of SPS allows students to become more active participants in their learning, thereby promoting deeper understanding and retention of scientific concepts. Moreover, research by Ahmad (2025) demonstrates that students who are proficient in science process skills perform better in science-related subjects because these skills foster critical thinking and problem-solving abilities.

SPS includes basic abilities in observation, classification, inference, prediction, and experimentation, noticing and describing phenomena; organizing objects or events according to their characteristics; drawing logical conclusions from observations, forecasting outcomes from patterns or evidence, and designing and conducting tests that explore scientific questions. Research shows that SPS such as inferential thinking does not develop automatically but rather improves gradually with repeated practice and instructional support. For instance, Nadalini et al. (2025) found that inferencing skills in high school learners matured over time and were enhanced when learners engaged in sustained opportunities to connect data to underlying principles. These skills give the foundation for scientific inquiry and allow students to approach problems and make decisions based on evidence (Akon-Yamga et al., 2024; Asare et al., 2022).

According to AlAli and Al-Barakat (2024), SPS are far from being an academic tool. They rather empower students to actively explore and engage with the natural world. Thus, through inquiry-based approaches, students are challenged to ask questions, test hypotheses, and analyze results to develop curiosity and independent thinking. All these skills are very key in the 21st century, where innovation and technology require a workforce able to think critically and solve problems adaptively (Koomson et al., 2024).

In Ghana, SPS are quite relevant to preparing students for entry into tertiary education and the fields of STEM careers. The SPS have been incorporated into the senior high school curriculum for Integrated Science to close the gap between theory and application. Mastering SPS will arm the student with skills relevant to Ghana's national development aspirations in the fields of science, technology, engineering, and mathematics (STEM). These skills will not only make individuals succeed in their academic performance but also contribute to the nation's larger ambitions of scientific and technological innovation (Bardoe et al., 2023).

This will also provide SPS with the ability to inculcate scientific literacy into the citizens, a necessity for making proper decisions regarding health, environmental conservation, and sustainable development. In this aspect, SPS are more than just academic tools; they constitute one of the key elements in developing a society that embraces and applies scientific reasoning to real-world challenges (Akon-Yamga et al., 2024; Koomson et al., 2024).

The role of SPS becomes even more significant in an attempt to handle both global and local challenges. For example, the understanding of issues in climate change, management of natural resources, and harnessing of renewable energy requires citizens and professionals to think analytically, reason critically about data, and develop solutions, all of which are centred on SPS. Asare et al., (2022) affirmed that equipping Ghanaian students with these skills puts them on par to participate in both national and global scientific contributions.

Finally, SPS form a basis that transcends academic achievement in the formation of individuals not only able but also ready to pursue careers in STEM and able to address some of the burning problems of today. Their presence within the curriculum in Ghanaian schools makes them particularly transformative in scientific literacy and a force to drive national development (Bardoe et al., 2023).

Science Process Skills (SPS) have been organized into two main categories, basic process skills and integrated process skills. Basic process skills represent the basic abilities of observation, classification, measurement, inference, and prediction. Thus, observation would entail becoming aware and recording information by use of senses, classification objects or data into meaningful groups. Integrated process skills, on the other hand, are advanced and involve the application of basic skills in combination. These include formulating hypotheses, designing and conducting experiments, analysing data, and controlling variables to ensure valid experimental results (Serevina et al., 2018; Zeidan & Jayosi, 2015). For example, experimentation involves using a structured approach to test hypotheses, while data interpretation allows for the analysis of findings to draw meaningful conclusions. Controlling variables ensures the reliability and validity of scientific investigations (Kouam, 2024).

However, there are challenges to the implementation of SPS in the teaching and learning process. Insufficient resources, inadequate teacher training, and large class sizes often become barriers to the effective teaching of these skills. Suryawati and Osman (2018) underlined that addressing these barriers to SPS teaching requires innovative approaches like contextual learning, which guarantees both engaging and resource-efficient educational experiences.

Science Process Skills form the basis of scientific literacy and are of great importance in developing skills related to the 21st century, such as critical thinking, problem-solving, creativity, and collaboration (Omar et al., 2012). In Ghana, this integration of SPS within the educational curriculum comes in line with global efforts to prepare students for the demands of the modern world. This would encourage the inquiry-based and STEM-oriented approaches proposed by the Ghana Education Service, to develop such skills for students in these areas (Essel et al, 2018). There is an urgent need to improve higher-order thinking by encouraging SPS, which include observation, classification, inference, prediction, and experimentation. The scientific literacy acquired can be helpful when the concepts in science are applied through the skills to obtain solutions to everyday problems (Asare et al., 2022). These skills are particularly important in tackling problems in renewable energy, environmental conservation, and resource management, which require both foundational knowledge and innovative problem-solving abilities. Incorporating SPS into the science curriculum has been shown to increase collaboration and communication skills, two key areas identified as critical to success in 21st-century learning environments. Bardoe et al. (2023) demonstrated that the integration of SPS with STEM fields can meaningfully prepare students to deal with interdisciplinary challenges.

The application of SPS to develop 21st-century skills, though very important, is very challenging in Ghana. Among the key barriers are a lack of resources, oversized classes, and a shortage of trained teachers who can effectively deliver inquiry-based learning. Vincent-Lancrin et al. (2019) argue that although critical thinking and problem-solving are foregrounded in policy reforms, these efforts are mostly undermined by resource constraints. In the same regard, Yeboah et al., (2017) observed that many schools still depend on rote learning methods, which impede the active engagement needed for the development of SPS and other 21st-century competencies.

SPS is very critical in equipping the Ghanaian student with skills that would enable them to surmount challenges thrown up by the 21st century. While tremendous strides have been made in harmonizing these SPS with world education trends, addressing resource gaps, improving teacher training, and harnessing technology are paramount if SPS is to make the greatest possible impact. The SPS with this effort will be a transformative force in moving forward science education and launching careers in STEM fields.

2.5.2 Gender differentials on students' acquisition of science process skills

Research into gender differentials in students' acquisition of science process skills continues to attract considerable attention, reflecting broader concerns about gender equity in science education (Yamtinah et al., 2017).

Darmaji et al. (2022) opined that science process skills encompass critical competencies such as observing, hypothesizing, experimenting, analyzing, interpreting, and communicating scientific information effectively. The acquisition and mastery of these skills are essential for scientific literacy and subsequently affect students' participation and success in science-related careers.

Studies revealed a trend regarding gender differences in the acquisition of science process skills. While historical studies frequently identified notable disparities between male and female students, contemporary research increasingly reports diminishing gaps, though differences persist in various contexts. Recent studies by Al-Balushi et al., (2022) and Archer et al. (2013) emphasised that, although explicit academic performance gaps have narrowed significantly, variations remain in attitudes, self-confidence, and engagement with specific science tasks. Al-Balushi et al., (2022) noted that male students often demonstrate greater confidence and preference for tasks involving physical manipulation and hands-on experimentation, such as constructing models or handling laboratory apparatus. These preferences potentially stem from traditional societal expectations and prior experiences that reinforce males' participation in physical and mechanical activities. Conversely, female students frequently excel in collaborative and communicative aspects of science inquiry, including teamwork, verbal articulation of ideas, and reflective discussions (Kilby, 2023). This proficiency may be influenced by socialization processes and classroom environments that encourage females to engage in cooperative learning and communication.

Similarly, Archer et al. (2013) documented that while performance disparities in science process skills are becoming less pronounced, differences in student confidence, interest, and engagement levels continue to subtly influence gendered participation and achievement. Their findings indicate that despite improved academic outcomes for female students, underlying attitudes toward science and perceptions of capability remain differentiated by gender. Female students tend to exhibit lower self-confidence in their motivation to learn physics, even when their actual performance is comparable or superior to that of male peers (Radulović et al., 2022). This disparity in confidence can lead to reduced participation and fewer opportunities to engage deeply with science tasks, potentially impacting longer-term interest and career aspirations in science fields. Archer et al. (2013) further argued that addressing these subtle yet significant differences require deliberate educational practices and targeted interventions aimed at boosting confidence, fostering positive science identities among female students, and actively challenging persistent gender stereotypes and biases

These findings align with work by Alam (2022) who argued that gender differences observed in science skill acquisition frequently arise from socio-cultural factors rather than inherent cognitive abilities. They emphasised the significant impact of educational practices, teacher expectations, and societal stereotypes on shaping students' science identities and skill development.

Moreover, contemporary pedagogical interventions designed to address gender stereotypes and biases are increasingly recognized as effective strategies for mitigating gender disparities in science skill acquisition. Brage-del-Río et al., (2025) highlight gender-sensitive teaching approaches, suggesting that active efforts to dismantle stereotypes and promote equitable participation substantially narrow skill acquisition gaps. Supporting this viewpoint, recent studies by Doucette (2024) and Robinson (2021) underscored the positive influence of inclusive instructional strategies and equitable laboratory experiences on girls' engagement and performance in science, advocating for structured pedagogical approaches to enhance female students' confidence and proficiency.

Despite these advances, persistent differences in students' engagement and confidence levels remain evident across different scientific disciplines. Contemporary literature consistently emphasises the importance of fostering equitable learning environments through inclusive curricula and culturally responsive teaching practices. These interventions aim to ensure equitable participation, enhance female students' confidence, and support comprehensive skill acquisition across gender boundaries.

2.6 Gender difference in academic performance in the study of science.

The exploration of gender differences in academic performance in science education continues to be a significant area of investigation, driven by ongoing concerns about achieving gender equity in educational outcomes. Academic performance in science entails students' achievement levels in knowledge acquisition, conceptual understanding, and practical application across scientific disciplines such as biology, chemistry, physics, electronics, and integrated science.

Despite all the research, disparities in science achievement between males and females persist in most parts of the world, even though in many areas the gap has narrowed. Male students often score higher in physics and engineering. On the other hand, female students tend to perform better in biology and life sciences. According to a study published by Ram et al. (2025) although the gender gap in STEM has narrowed over recent decades, it still remains large in advanced courses and higher education.

A study published in the International Journal of Evaluation and Research in Education indicated that while no significant gender differences were observed in science academic achievement among Grade 4 and Grade 8 students in China, variations existed in scientific interests and creativity, suggesting that factors beyond academic performance contribute to gender disparities in science education (Jia, et al., 2020).

Similar trends can be seen in Ghana. The research evidence has shown that, generally, boys perform better than girls in physics and chemistry but girls performed better in biology (Akon-Yamga et al., 2024). It has been held that this results from societal expectations of the performances of boys and girls, stereotypical gender roles, and inequalities in access to resources and opportunities. Also, cultural perceptions about the roles of men and women in science-related fields bear on academic performance as well (Quarshie et al., 2023).

A study by Rozgonjuk et al. (2024) indicated that traditional gaps in academic performance between male and female students in science subjects have generally diminished, although differences persist in specific contexts. Wang and Degol (2017) opined that there is a reduction in gender disparities across most scientific disciplines, attributed to enhanced pedagogical strategies and greater societal awareness of gender issues.

Specifically, in electronics and electricity education, contemporary research has revealed distinct patterns of gender differences. For instance, a study by Foley et al. (2016) highlighted that male students typically show higher confidence and slightly better performance in electronics-related tasks involving circuit construction and troubleshooting. This difference is often attributed to earlier socialization experiences and exposure to electronics, typically more prevalent among male students. However, the same research emphasised that targeted educational interventions, including cooperative learning and structured lab activities, significantly reduce performance gaps and increase female students' confidence and proficiency in electronics and electrical science.

The methods used to teach science contribute substantially to the shape of gender differences in academic achievement. Traditional teacher-centered approaches, such as lecturing and rote memorisation, have been shown to put boys at an advantage, since those methods emphasize competition and individual achievement (Gbordzekpor et al., 2023). In contrast, girls tend to perform better where there are possibilities for interaction with peers and also getting support from teachers in cooperative learning environments (Wrigley-Asante et al., 2023). Wrigley-Asante showed that the teaching methodologies bear a significant influence on gender differences in STEM education in Ghana, where teacher-centered approaches limit possibilities of engagement among female students. Numerous researches support the utilization of inquiry-based and problem-based learning in lessening gender disparities in science education (Gbordzekpor et al., 2023). These approaches encourage active participation, cooperation, and hands-on activities that have proven to increase interest and comprehension among school girls.

Similarly, research by Eze et al. (2021) found that female students, despite initial lower self-confidence in electronics and electrical engineering, demonstrated substantial academic performance improvement following participation in collaborative, project-based learning environments. Such environments encouraged active participation, fostering enhanced practical skills and deeper conceptual understanding among female learners.

Another study conducted recently at the senior high schools in Ghana by Appiah-Twumasi et al. (2024) found that girl students exposed to PBL have developed confidence in the science-related subjects with substantial improvements in academic performances. The research concluded that these active learning strategies not only enable girls to enhance their understanding of scientific concepts but also spark interest and motivation to possibly consider careers in fields of science. In addition, teacher attitudes and behaviors can affect gender differences in science achievement. Britwum et al. (2024) indicated that teachers often unconsciously give more attention, praise, and encouragement to boys to take risks in problem-solving activities. Though such behaviours are relatively subtle, they have a cumulative effect of making the classroom more boy-friendly and girls often feel neglected or otherwise less encouraged to participate in science activities fully.

Broader research by Reilly et al. (2016) supports these findings, indicating reduced gender disparities in science achievement among high school students. Their findings suggest that girls frequently perform comparably or even better in biology and chemistry, although slight performance advantages for boys continue to exist in physics and electronics, particularly in areas requiring spatial and practical manipulation skills.

Another major determinant of gender differences in science achievements is access to educational resources, such as textbooks, laboratory equipment, and extracurricular science programs. In most developing countries, including Ghana, girls are often denied access to these resources as much as boys are. This situation limits their opportunities to participate in hands-on learning experiences, which are important in developing scientific skills and knowledge. Wrigley-Asante et al. (2023) commented that the unequal distribution of resources within schools affects female students most, especially in rural areas where there is usually very poor provision of science equipment and laboratory facilities. A study by Ansong et al., (2020) emphasized that in resource-constrained environments, girls are less likely to participate in science experiments or any other out-of-classroom activities in science, like science clubs. This gives them very minimal practical science experiences and further widens the existing gap in academic performance between the genders. Evidence will also show that boys will have more chances to explore scientific concepts through practical activities, further deepening the inequalities.

Voyer and Voyer (2014) underscored girls' typically stronger performance in classroom-based assessments and coursework across various scientific disciplines due to superior organizational abilities and collaborative skills. However, standardized assessments focusing heavily on abstract reasoning and quantitative skills continue to show marginal performance advantages for boys, particularly in physics and electronics.

Socioeconomic factors further heighten these disparities. For example, Kuteesa et al. (2024) have shown that students from low-income families, especially girls, often do not have access to private tutoring, digital tools, and online learning platforms that can enrich learning outcomes in science. The unequal access to those resources impairs not only the academic performance of girls but also their interest in pursuing science-related careers.

This would require more focused interventions at improving resource allocation in enhancing gender equity in scientific education. More investment in education in the rural setting, including building gender-inclusive science facilities and mentorship programs for the girl child to position her to lead in STEM careers (Adams & Baddianaah, 2023: Gbordzekpor et al., 2023).

Current research also highlights that gender differences in academic performance often stem from variations in self-confidence, motivation, and perceived competence in science. Eccles and Wang (2016) emphasised that despite comparable academic results, female students report lower self-confidence and higher anxiety in physics and electronics, limiting their continued engagement and performance in these disciplines.

Student attitudes towards science are very important for academic outcomes, and these attitudes get largely framed through the influence of gender dynamics. Boys usually tend to show a higher level of interest and motivation toward science subjects, mainly in the fields of physics and engineering. On the other hand, girls show more interest in biology and environmental science. This gendered pattern is perpetuated by societal and cultural stereotypes that associate certain scientific disciplines with either masculinity or femininity (Wrigley-Asante et al., 2023). It has been well documented that, with enabling learning environments and the right support, girls perform as well as or even better than boys in science subjects. For example, Sakpla et al., (2023) depicted that female role models in the STEM area in Ghana really shape girls' interests, confidence, and performances regarding science subjects. Such interventions open up more gender-inclusive opportunities and initiate the closing of the gender gap science educational. Evidence has also shown that mentorship programs targeted toward girls and collaborative learning environments have a positive influence on girls' attitudes toward science (Bardoe et al., 2023).

Master and Meltzoff (2020) further confirmed that persistent stereotypes and biases influence students' self-concepts, particularly affecting female students' confidence and subsequent achievement in traditionally male-dominated fields such as electronics and electricity. Their research highlighted that societal and educational stereotypes suggesting innate male superiority in certain scientific areas continue to negatively impact female students' perceptions of their abilities, even when academic performance data show comparable achievements between genders. Master and Meltzof (2020) advocated strongly for explicit educational interventions that actively confront and challenge these stereotypes, incorporating strategies such as stereotype threat reduction, inclusive curriculum designs, and role modeling to promote positive science identities and increased confidence among female students. Such targeted interventions have shown promising results in reducing the psychological barriers and improving overall academic outcomes for female students in science education.

Pedagogical strategies promoting gender equity in electronics and science education have been highlighted in contemporary literature. Studies by McGuire et al. (2020) and Nguyen et al. (2021) demonstrate that inclusive instructional strategies, including collaborative learning, culturally responsive teaching, and the active dismantling of stereotypes, substantially improve academic performance, engagement, and confidence among female students.

2.7 Students' Academic performance in electrical energy and electronics concepts

Across the globe, educators have observed persistent challenges in student performance regarding electrical energy and electronics concepts, with learners frequently struggling to bridge the gap between abstract theory and practical application. Physics education research consistently identifies several key factors contributing to these difficulties including negative attitudes among both students and teachers, limited hands-on learning opportunities, and deeply rooted misconceptions about fundamental electrical principles (Daleon & Quirap, 2022; Assem et al., 2023).

In West Africa, examination reports from the West African Examinations Council (WAEC) consistently show average or below-average performance in technical subjects like Applied Electricity, with chief examiners noting particular difficulties with circuit analysis and power calculations (WAEC Chief Examiners' Report, 2020). This pattern is not geographically isolated. Similar concerns about electronics education outcomes emerge consistently across Asian and other developing educational contexts (Chen et al., 2024).

However, research demonstrates that with appropriate instructional approaches, students can achieve strong outcomes in these technically demanding subjects. A compelling example comes from the Philippines, where senior high school students in an Electrical Installation and Maintenance program achieved "very satisfactory" average grades in their electronics coursework (Daleon & Quirap, 2022). Notably, these students also exhibited advanced practical competencies in wiring and cabling tasks, with statistical analysis revealing a significant positive correlation between hands-on skill proficiency and theoretical understanding (Assem et al., 2023). This evidence strongly suggests that integrated, practice-rich curricula can effectively enhance both conceptual understanding and applied skills in electrical subjects.

2.8 Gender Schema Theory in Science Education

Gender differences in science education have been a concern for a long time, especially in areas such as electronics and electrical energy that are traditionally thought of as characteristically male dominated. Bem (1981) introduced the Gender Schema Theory (GST) which has proven to be one of the most effective models for explaining such differences. According to this theory, individuals form mental models (gender schemas) through societal and cultural expectations that instruct them in the way they think and behave (Bem, 1981). Schemas instruct children from as young an age as infancy to meet gender-typical behavior. In science and STEM learning contexts, these schemas are a significant component of student self-concept, interests, and academic performance.

In science teaching and learning, GST provides a clue to the manner in which gender perception of ability might influence students' results. For example, girls have taken an approach to viewing science, particularly physical sciences and electronics, as man's territory. This perception is accompanied by low confidence, poor participation, and lower academic achievement, although equal in competence. A study by Tomas and O'Grady (2016) suggested that female students' confidence in science is tied to their gender role perception within scientific areas. Similarly, a study by Archer et al. (2013) suggested that the majority of girls identify science with masculinity and often envision scientists as males and perceive science professions as being at odds with their identity.

These gender schemas have real consequences on science process skills learning and academic performance. Girls' gender schemas inadvertently lead them to avoid science activities, which eventually has an effect on them in the long term on issues like experimentation, observation, and inferring. Research conducted by Meece and Painter (2008) highlighted that girls' perceptions of science as a male-dominated field significantly impact their confidence and engagement. When science is viewed through a gendered lens, girls often experience reduced confidence, which in turn leads to lower motivation and diminished participation in STEM subjects. This trend not only affects their immediate academic choices but also limits their career opportunities and contributions to the scientific community in the future. Meece and Painter (2008) stated that the differences are not biological but are determined by external factors such as teacher expectations, classroom environment, and curriculum design. In addition, a global survey by Nosek et al. (2009) determined that gender stereotype countries in science were considerably more divergent in boy and girl achievement levels on science standard tests.

Pedagogy is also instrumental in the reinforcement or clarification of these gender schemas. The traditional didactic-teaching pedagogy can potentially do so unintentionally with the prevailing, competitive behavior slanting induced in boys by society. Alternatively, Problem-Based Learning (PBL) is a more general and collaborative pedagogy that can transcend gender differences. PBL emphasises resolving problems in authentic contexts, collaboration, and learner-centered learning, which have been found by research to help counteract stereotype threat and increase female learners' competence and confidence.

For example, a study in Nigeria found that male and female secondary students taught algebra through problem-based learning did not differ significantly in achievement or retention, indicating that both genders benefited equally from the approach (Ajai & Imoko, 2015). Similarly, a Ghanaian study on pre-service science teachers reported no gender gap in integrated science performance, highlighting that when learning opportunities are equal, female students perform on par with their male counterparts (Sakyi-Hagan & Hanson, 2022). Additional research in Ghana also found no meaningful difference in mathematics outcomes between boys and girls, suggesting that any minor variations are more likely influenced by factors such as stereotype threat or teaching methods rather than inherent ability (Marifa et al., 2025). These converging findings indicate that problem-based and active learning strategies can support gender parity in STEM education, with any observed performance differences being minimal and not reflective of systemic gender effects.

In light of this background, it is urged that science teachers assess their pedagogy and educational materials critically. By fostering diversified learning environments, incorporating gender-free language, and highlighting diverse science role models, teachers can allow students to break down restrictive gender schemas. UNESCO (2017) also agreed with such a call, advocating system-wide education policy and curriculum reform to facilitate girls' and women's inclusion in STEM.

2.9.1 Perceptions of students on the use of problem-based learning in science lessons.

Problem-Based Learning (PBL) has emerged as a student-centered pedagogical approach increasingly employed in science classrooms (Rahman et al., 2024). Rahman et al. (2024) further stated that this method emphasises active learning by engaging students in solving real-world problems, which fosters deep conceptual understanding and critical thinking.

Numerous studies have explored student perceptions of PBL, generally indicating positive attitudes and acknowledging various benefits and some challenges associated with its implementation.

Recent researches have consistently highlighted favorable student perceptions regarding PBL's role in enhancing understanding and engagement in science lessons. For instance, Beagon et al. (2019) found that students perceive PBL as highly effective in stimulating interest and active participation, noting significant improvements in their motivation and enjoyment during science lessons. Students reported feeling more involved and interested in learning when lessons were structured around realistic, complex problems requiring collaborative exploration. Specifically, students highlighted that the interactive nature of PBL encouraged them to actively share ideas, debate possible solutions, and collectively arrive at conclusions, which significantly enhanced their social and cognitive engagement. Additionally, Sam (2024) opined that student appreciated the shift from passive memorisation to active inquiry, which led to increased intrinsic motivation and enthusiasm for scientific inquiry, making learning both enjoyable and intellectually stimulating.

Nguyen et al., (2021) suggested students appreciate PBL’s emphasis on practical applications and real-world relevance, recognizing that it facilitates the meaningful application of scientific concepts across various disciplines. Students specifically highlighted how PBL enabled them to better understand complex scientific ideas by actively solving problems that required integrated knowledge from biology (Usman et al. 2023), physics (Marcinauskas et al. 2024), and environmental science. Students described how engaging in interdisciplinary problem-solving activities provided them with the opportunity to see direct connections among diverse scientific fields, enhancing their ability to apply theoretical concepts practically. Furthermore, research reported that the contextualization of scientific knowledge through real-world problems made science lessons more interesting, relatable, and meaningful, significantly improving students reported that the contextualization of scientific knowledge through real-world problems made science lessons more interesting, relatable, and meaningful, significantly improving their motivation and long-term retention of the material. motivation and long-term retention of the material (Osika et al., 2022).

Moreover, recent findings by Helaluddin et al., (2023) underscored students' positive perceptions of PBL's role in promoting critical thinking and problem-solving skills. Students noted significant benefits from engaging in collaborative activities, emphasizing how group discussions and interactive problem-solving processes improved their ability to analyze information critically and creatively generate solutions to scientific challenges. Helaluddin et al., (2023) further asserted that Students also expressed appreciation for the structured yet flexible nature of PBL activities, allowing them to approach problems from multiple perspectives and consider diverse solutions. They particularly valued the opportunities to articulate and defend their reasoning, receiving peer feedback and refining their ideas through group discussions. This interactive process was perceived as instrumental in enhancing their analytical skills, fostering creativity, and promoting deeper conceptual understanding.

Despite generally positive perceptions, research has also identified several challenges students encounter with PBL in science contexts. Study by Aldabbus (2018) reported students initially experiencing difficulty adjusting to the open-ended nature of PBL tasks, highlighting feelings of uncertainty and frustration due to the lack of clear instructions or structured guidelines. However, students gradually overcame these initial challenges through sustained exposure and guidance, ultimately recognizing the value of independent inquiry and autonomy in the learning process.

Furthermore, research by Mutanga (2024) indicated that students perceive PBL as demanding considerable cognitive effort and effective time management skills. Students reported that navigating complex, real-world problems required substantial cognitive engagement, such as identifying relevant information, distinguishing essential from non-essential details, and integrating knowledge from various scientific domains. Although many students acknowledged these demands as beneficial for developing deeper learning, critical thinking, and effective organizational skills, they emphasized the importance of clear instructor guidance, structured scaffolding, and timely feedback. Students highlighted that structured scaffolding helped break down complex problems into manageable tasks, enabling them to progress more confidently through the learning process. Additionally, timely and constructive feedback from instructors was perceived as crucial in clarifying misunderstandings, guiding ongoing learning, and enhancing students' overall confidence and success within PBL frameworks.

In addition, Tan et al. (2021) identified student perceptions of group dynamics as a critical factor influencing their experiences with PBL. While most students appreciated collaborative learning, some reported challenges such as unequal participation, communication barriers, and conflicts within group activities. These experiences highlighted the necessity for structured facilitation and clear expectations to enhance positive interactions and equitable participation among students. Students emphasized the importance of clearly defined roles and responsibilities within groups to ensure active engagement and fairness. Furthermore, they suggested that instructors should regularly monitor group activities, offering timely interventions to resolve conflicts and encourage balanced participation. Positive group experiences, as reported by students, were linked to improved learning outcomes, enhanced interpersonal skills, and increased satisfaction with the learning process, underscoring the critical role of effective group management strategies in maximizing the benefits of PBL.

Cooperative and interactive approaches like group work and inquiry-based learning tend to favor girls while competitive and individualistic approaches tend to favor boys. Wrigley-Asante et al. (2023) indicated that such preferences are consistent with broader patterns in education, where girls tend to do better in supportive, collaborative learning environments while boys perform better in competitive and challenge-based ones. Many students, especially girls in Ghana, complain of a lack of connection to the abstract nature of the traditional lecture mode of teaching. They feel it is not relevant to real-life situations. Bardoe et al., (2023) showed that when girls are exposed to inquiry-based and technology-enhanced instruction, their interest and motivation in science increase considerably. Such teaching methods allow for exploration and collaboration, which resonate more with the learning styles of female students. Additionally, a study by Norhaslina et al. (2025) indicated that schools with student-centered learning approaches such as Problem-Based Learning (PBL) have reported increased academic benefits among female students. Norhaslina et al. (2025) have proved that incorporating PBL and other active learning strategies increases interest and performance among girls. Results showed the necessity of introducing teaching strategies into a classroom environment that are inclusive and diverse enough to cater for a variety of learning needs among all students.

2.9.2 The Importance of Learner Perception in Pedagogy Effectiveness

The success of any instructional approach is not solely a product of its theoretical basis or instructional design, but also of student perception. Student perception plays a key role in determining engagement, motivation, and learning (Farah & Al-Hattami, 2023). Students will cognitively and emotionally engage with course content if they find an instructional approach meaningful, inclusive, or attuned to their learning style.

In constructivist pedagogies such as Problem-Based Learning (PBL), perceptions of the learner are especially significant. PBL is designed to promote active learning, autonomy, and collaboration, attributes that will be welcomed by some students but will be threatening to others. Schmidt et al. (2007) contended that students' perceptions of PBL as either empowering or overwhelming are a key factor in determining the extent to which they develop critical thinking and problem-solving abilities.

Brandstätter and Bernecker (2022) identified that when students perceive an instructional method as achievable and supportive, they will be more persistent when confronted with difficulties. If a method, on the other hand, is perceived as irrelevant or too difficult, students will disengage regardless of its pedagogical merit. Schmidt et al. (2007) maintained that students' own belief about PBL as being empowering is a determining factor of the extent to which they develop problem-solving and critical thinking skills.

There is evidence that student achievement is mediated by student perception in the relationship between teacher behavior and student achievement. Teacher responsiveness, clarity, and warmth become more effective if students see them as authentic (Jafarpoor et al., 2025).

Within science education, this conflict is worsened by pervasive assumptions of the difficult nature of science. Those students who find their science classrooms to be fun, meaningful, and welcoming are more engaged and effective (Osborne et al., 2023). Specifically, concerns of inclusivity, in which students perceive that their identities and contributions are respected, have been found to be a driver of participation, especially among underrepresented groups (Gay, 2018).

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter describes the methodology used for the study. It includes research paradigm, research design, population, research instrument, validity and reliability, data collection procedure including pre-intervention procedures, the intervention and the post-intervention activities, data analysis techniques and ethical considerations.

3.1 Research paradigm

This research adopted the pragmatism paradigm as it aligns with the mixed method approach which combines both quantitative and qualitative techniques to address a research problem comprehensively. According to Feilzer, (2024) and Morgan, (2022), Pragmatism emphasises the practical application of research methods to answer specific questions, focusing on solutions that work in real-world contexts.

Feilzer (2024) further indicated that, contrary to other research paradigms that are confined to either a quantitative or qualitative approach, pragmatism combines both to develop an in-depth understanding of relationships among variables. In this study, the quantitative aspect involved collecting data through experiment and standardized tests to study the relationship that exists between problem-based learning and its impacts on science process skills acquisition and academic performance. Qualitative data was obtained using interview guide. This provided in-depth information regarding the experiences and perceptions of the students to complement the numeric data from quantitative analysis (Morgan, 2022; Klimstra & Johnson, 2025).

The pragmatist paradigm values practical outcomes, emphasising the use of diverse tools and approaches to identify patterns, test hypotheses, and propose actionable solutions to real-world challenges. Adopting pragmatist paradigm for this study conformed to Feilzer (2024) and Parnis, (2023) that, pragmatist paradigm generate knowledge that is not only empirically valid but also meaningful and applicable in problem-based learning, academic performance and science process skill acquisition.

3.2 Research Design

This study employed quasi-experimental research design, specifically the non-equivalent groups design. According to Gribbons and Herman (2019), quasi-experimental research design is a research design that is used to test the cause-and-effect relationship between variables, as in experimental designs. Gopalan et al. (2020) however asserted that in quasi-experimental studies, unlike in true experimental designs, there is no random assignment to either treatment or control group. In the nonequivalent groups design, the participants would be pre-grouped, without using random allocation into the treatment and control groups. For this research, one group was given the intervention, which is problem-based learning, while the other group receives instructions through lecture method. In this design, both groups underwent pre-tests and post-tests to measure the dependent variables (science process skills acquisition and academic performance). The pre-test served as a baseline for comparison, whereas the post-test outlined the changes the intervention yields. While the nonequivalent groups design does not entirely negate the potential of confounding variables, it is an efficient means by which interventions could be reviewed in classroom situations, even in natural settings (Krishnan, 2019; Gopalan et al., 2020).

3.3 Population

Shukla (2020) define population as the entire units carrying the variables being measured since it represents a group that the findings of research can be applied. It, therefore, means that the findings obtained through research are representative of all such units so that the conclusion of research is relevant to all units concerned. According to Creswell (2014), a target population is a specific group of individuals or entities that researcher intends to study to collect data, test hypotheses, or evaluate interventions' effectiveness. In addition, Creswell (2014) defined the accessible population as the designated criteria that are accessible to the researcher as a pool of subjects for a study. Creswell (2014) further stated that researcher usually sample from an accessible population and hope to generalise to a target population. The target population for this study was thirty thousand five hundred and thirty-two (30,532) second year Senior High School students in the Volta Region that study integrated science. The accessible population was one thousand three hundred sixty-one (1361) second year Senior High School students in South Dayi District of Volta Region.

3.4 Sampling Technique and Sample

Sampling refers to the process of selecting a portion of a population (Alvi, 2016; Creswell, 2014). According to Shukla (2020), the size of the sample selected for a study is immaterial and depends solely on what the researcher is researching into. For this study, the researcher employed purposive sampling technique to select the sample for the study. Two senior high school form 2 classes were selected. The sample size for the study was 95 students. One intact General Arts class of 49 students consisting of 26 females and 23males from Peki senior high school was used as experimental group. An intact General Arts class of 46 students made up of 27 females and 19 males from Peki Senior High Technical school was used as the control group. Students with General Arts, History option were the participants for the study. The form two classes were selected on the bases that; the intervention lesson was based on form two topics. The students lack the basic science process skills coupled with poor performance in integrated science. These students are also not exposed to any other science related subject apart from Integrated science.

3.5 Instruments for Data Collection

3.5.1 Test (SSAT and SPSAT)

A test is a systematically designed instrument used to measure an individual's knowledge, skills, abilities, or performance in a specific domain. According to Linn and Miller (2019), a test is a set of tasks or questions presented under standardized conditions with the purpose of eliciting information about a learner's achievement or competence. In educational research, tests serve as objective tools to assess learning outcomes, diagnose strengths and weaknesses, and compare the effectiveness of instructional strategies.

Two achievement tests were used to collect pre-test and post-test data. Students' Science Achievement Test (SSAT) was used to measure students' academic performance using 20 multiple-choice items drawn from the SHS Integrated Science syllabus on electrical energy and electronics. Students selected correct options and justified their answers. The total score for both the pre-test and post-test was 20 marks each.

The Science Process Skills Achievement Test (SPSAT**)** was used to assess students' process skills through 10 theoretical–practical questions. The total score for the pre-intervention and post-intervention SPSAT was 20 marks each. The items focused on assessing observation, measuring, inferring, predicting, and classifying skills.

3.5.2 Questionnaire

A questionnaire is a systematic tool for gathering data, typically composed of structured or semi-structured questions designed to capture participants' views, experiences, or behaviours in a measurable form (Creswell & Guetterman, 2019). For this study, a carefully designed questionnaire was developed to obtain quantitative data on students' perceptions of problem-based learning (PBL) in Integrated Science. The instrument consisted of statements rated on a 5-point Likert scale ranging from Strongly Disagree (*1*) to Strongly Agree *(5)*. Prior to administration, the items were subjected to an item analysis to identify and adjust statements that could weaken the internal consistency of the scale. The Statistical Package for the Social Sciences (SPSS, Version 26) was then used to calculate the Cronbach's alpha reliability coefficient, which produced a value of 0.79. This outcome exceeded the recommended minimum threshold of 0.70 for acceptable internal consistency and was therefore considered evidence of reliability. Other scholars, such as Ekolu and Quainoo (2019) acknowledge that in educational research where conclusions are applied at the group level, even coefficients in the range of 0.50–0.80 may be tolerable. Thus, the questionnaire in this study demonstrated sufficient reliability for meaningful interpretation.

3.5.3 Interview guide

An interview guide is a carefully constructed protocol of questions or prompts used in qualitative research to elicit rich, detailed responses while ensuring consistency across interviews. Cheron et al. (2022) stated that such guides help researchers maintain comparability among interviews yet allow respondents flexibility in expressing their experiences and perspectives. Unlike structured questionnaires, an interview guide is particularly suited for exploring attitudes, lived experiences, and nuanced perceptions in depth (Gupta et al., 2025; Westland et. al 2025).

To complement the quantitative data, a structured interview guide consisting of five open-ended items was also employed. The interview guide was designed to probe more deeply into students' perspectives on the use of PBL in the teaching and learning of electrical energy and electronics. This qualitative component allowed students to articulate their experiences in their own words, adding depth to the statistical findings and enhancing the validity of the study through methodological triangulation.

3.5.4 Observation Checklist

An observation checklist is a structured tool that outlines specific behaviours, skills, or activities to be observed and rated systematically during a teaching and learning process. It provides clear criteria for data collection, ensuring that observations are consistent, objective, and aligned with the study's research objectives (Cohen et al., 2011; Creswell, 2012). Unlike informal observation, an observation checklist reduces subjectivity by focusing attention on predetermined indicators of performance.

The use of an observation checklist is critical in educational research because it ensures accuracy, reliability, and comparability of data. It provides standardised criteria for measuring learners' competencies, reducing observer bias. The checklist also allows for the systematic collection of evidence on learners' behaviours and skills as they occur naturally in classroom or laboratory settings. In addition, it supports triangulation of data by complementing other instruments such as tests and interviews, thereby strengthening the validity of findings (Denscombe, 2014). In this study, the checklist was particularly important for capturing the demonstration of science process skills (observing, measuring, inferring, predicting, and classifying), which are best assessed through direct observation of learners' actions.

The observation checklist was employed during lessons on Electrical Energy and Electronics to assess learners' performance in science process skills. The checklist was structured into five categories. i.e observing, measuring, inferring, predicting, and classifying. Each of the skills was rated on a 0–4 scale. The researcher used the checklist to record learners' behaviours while they conducted practical activities such as setting up circuits, measuring current, and interpreting results. Scores were assigned based on the clarity, accuracy, and consistency of learners' actions. These observations were later analysed alongside test scores and interview data to provide a holistic picture of learners' skill development and to evaluate the effectiveness of the intervention.

3.6 Validity and Reliability of the Instruments

Validity refers to the degree to which a test measures what it is supposed to measure and, consequently, permits appropriate interpretation of scores (Creswell, 2014). An instrument is considered valid when there is confidence that it measures what it is intended to measure in a given situation (Punch, 2013).

The content validity of test items was determined by ensuring that, questions for both the pre-test and the post-test are set from the selected topics used for the research and are within the scope of the Ghana Education Service approved syllabus for integrated science in senior high schools to ensure a fair and representative sample of questions.

To ensure that participants' scores from the pre- test and post-test are valid, meaningful and to ensure good conclusions from the sample studied and the research population, both test instruments was presented to experts in physics education and senior high school integrated science teachers for scrutiny. Also, the draft questionnaires and interview guide was shown to the researcher's supervisor and some experienced science educators and integrated science teachers for scrutiny.

3.7 Reliability of the Instrument

Reliability refers to the consistency of a research instrument to produce similar results under similar conditions. According to Orçan (2023) a reliable research instrument should ensure that measurements are free from random errors, producing dependable and replicable data over time or across different settings and must be devoid of any ambiguities. This means that scores from an instrument should be stable and consistent and should be nearly the same when researchers administer the instrument multiple times at different times. The more reliable a test is, the more confidence we can have that the scores obtained from the test are essentially the same scores that would be obtained if the test were re administered to the same test takers at another time or by a different person (Livingston, 2018). The questionnaire was pilot-tested on 10 form two students in Peki Senior High School to ensure clarity and reliability before being administered to the full sample.

The reliability of the items was tested using McDonald's Omega reliability coefficient ($\omega \geq 0.70$). McDonald's Omega (ω) is a reliability coefficient used to measure the internal consistency of a research instrument (Malkewitz et al., (2022). It provides an estimate of how well the items in a test or questionnaire reflect a single underlying construct. Unlike Cronbach's Alpha, which assumes that all items contribute equally to the construct being measured, McDonald's Omega allows for unequal contributions by accounting for the different factor loadings of each item (Orçan, 2023). Items that had McDonald's Omega coefficient less than 0.70 (ω ≥0.70) were reconstructed. According to Malkewitz et al., (2022), the coefficient is high when its absolute value is greater than or equal to 0.7, otherwise it is considered to be low. A high coefficient implies high correlation between variables indicating a high consistency among the variables.

3.8 Data Collection Procedure

Data collection involved three main activities, namely pre-intervention activities, intervention activities and post-intervention activities. Each of these activities is described in details as follows;

3.8.1 Pre-Intervention

The pre-intervention activity began with indexing the participants. Participants in the experimental group was assigned index numbers. EGF was prefix for females in the experimental group and EGM for males in the experimental group. Participants in the control group was indexed as CGM and CGF for males and females respectively.

The pre-intervention tests were administered after indexing the participants. They consisted of two parts; the Students' Science Achievement Test (SSAT) and the Science Process Skills Achievement Test (SPSAT). The SSAT comprised 20 multiple-choice questions designed to assess students' academic performance in electrical energy and electronics. Items were drawn from the Senior High School Integrated Science syllabus and focused on areas such as voltage, current, resistance, power, circuit analysis using

Ohm's and Kirchhoff's Laws, energy consumption, and the functions of electronic components including resistors, capacitors, diodes, and transistors.

The SPSAT consisted of 10 theoretical–practical questions, each carrying two marks, making a total of 20 marks. These items assessed students' ability to observe, measure, infer, predict, and apply experimental reasoning within the context of electrical energy and electronics.

Both tests were administered together within 60 minutes under standard examination conditions to ensure fairness and reliability. The SSAT questions had four answer options (A–D), with one correct answer, while the SPSAT required written explanations to support responses. Structured marking rubrics were applied to ensure objectivity and consistency, with each correct SSAT response earning one mark and each SPSAT item scored out of two. Answer sheets were collected immediately after completion to maintain integrity. The scores provided baseline data on students' academic performance and science process skills before the intervention.

3.8.2 Intervention Activities

Educational interventions according to Creswell and Guetterman (2019), are structured instructional activities or programs purposefully designed by the researcher to bring about change in knowledge, skills, or behaviour. Similarly, Fraenkel et al. (2021) explained that interventions are systematically planned and implemented to examine cause-and-effect relationships and to evaluate the impact of specific pedagogical practices. In this study, weekly lesson plans were carefully developed for both the Experimental Group and the Control Group in line with the Senior High School Integrated Science curriculum.

Teaching and learning activities were structured with weekly objectives designed to build on students' previous knowledge. The intervention lasted for six weeks, with the Experimental Group receiving instruction through the problem-based learning (PBL) approach, while the Control Group was taught using the conventional lecture-based method.

In the Experimental Group, students were divided into small groups of five and actively engaged in collaborative, problem-solving activities. The researcher provided all required materials and acted as a facilitator, guiding discussions, scaffolding learning, and ensuring that students made connections between theoretical principles and practical applications. During each lesson, the researcher used observation guide to conduct formative assessment. Students' formative assessment scores were recorded before the next lesson. This continuous assessment enabled the researcher to collect data on students' mastery of the five science process skills being measured. Group discussions on the feedback ensured that weaknesses in understanding concepts such as Ohm's Law, circuit analysis, and component functions were addressed.

The Control Group, on the other hand, was taught using a teacher-centered lecture method. Lessons were delivered mainly through direct explanation, chalkboard illustrations, and worked examples. Students solved structured textbook-based problems under the teacher's guidance, while practical demonstrations were limited and carried out solely by the teacher. Instruction in this group followed a linear sequence, designed to consolidate theoretical understanding of electrical energy and electronics but without opportunities for collaborative exploration or problem-solving activities. Find Details of the lesson plans for the six weeks at appendix

3.8.2.1 Control Group

The control group which consisted of 46 students from an intact General Arts class at Peki Senior High Technical School served as the reference point for evaluating the effectiveness of the problem-based learning (PBL) intervention. Over a six-week period, the group was taught through lecture-based instruction, with each lesson lasting up to 100 minutes. The instructional approach was purely theoretical and teacher-centered, devoid of problem-solving or collaborative activities, as the teacher delivered concepts in electrical energy and electronics primarily through chalkboard illustrations, worked examples, and textbook explanations.

In Week 1, students were introduced to the fundamental concepts of electric current, voltage, and resistance, during which the teacher explained Ohm's Law using formulas and demonstrated its application through numerical examples.

In Week 2, the focus shifted to power and energy consumption, with the teacher guiding students through calculations of electrical power and energy using standard equations and textbook-based exercises.

In Week 3, lessons covered series and parallel circuits, where students observed teacher-drawn circuit diagrams on the chalkboard and learned how to determine total resistance, current, and voltage distribution in both types of circuits.

In Week 4, the teacher presented the topic of electronic components including resistors, capacitors, and diodes, explaining their functions theoretically and using symbolic representations without any practical demonstrations.

In Week 5, the lesson was devoted to measuring instruments such as voltmeters, ammeters, and multimeters, with explanations provided on their uses and rules for connection in circuits. In the final week, Week 6, a comprehensive review session was conducted, during which the teacher revisited all previously taught concepts and guided students through problem-solving exercises designed to consolidate their understanding.

Throughout the six-week period, students were encouraged to take detailed notes during lessons and study at home. This instructional approach was intended to strengthen their conceptual understanding of electrical energy and electronics.

3.8.2.2 Experimental Group

The experimental group, made up of 49 Form Two General Arts students from Peki Senior High School, received instruction in Electrical Energy and Electronics through the Problem-Based Learning (PBL) approach. Teaching spanned six weeks, with each lesson lasting up to 100 minutes. Unlike the control group, these students engaged in inquiry-driven, collaborative, and problem-solving activities, with the teacher serving primarily as a facilitator rather than a lecturer.

In Week 1, students were introduced to the concepts of current, voltage, and resistance through a practical scenario on household electricity consumption. Working in groups, they applied Ohm's Law to analyse the problem, performed guided calculations, and discussed the implications of their findings.

In Week 2, the focus shifted to power and energy consumption. Students explored the problem of rising electricity bills, calculated the energy use of different household appliances, and suggested strategies for improving efficiency.

During Week 3, the lesson centred on series and parallel circuits. Learners constructed circuits using basic kits, measured current and voltage at different points, compared their observations with theoretical expectations, and reflected on sources of error.

In Week 4, students investigated electronic components such as resistors, capacitors, and diodes by examining real-life situations involving faulty electronic devices. They identified component functions, interpreted circuit symbols, and proposed possible solutions.

In Week 5, attention was given to measuring instruments such as voltmeters, ammeters, and multimeters, where students worked in groups to determine the correct methods of connection, tested circuits practically, and discussed sources of inaccuracy as well as safety measures. Finally, in Week 6, students undertook an integrative project that required them to design, wire, and present a simple household circuit, drawing on all the concepts learned in the previous weeks.

Throughout the intervention, students collaborated in small groups, shared ideas, and engaged in reflective discussions about their problem-solving processes. The teacher guided learning by posing probing questions, clarifying misconceptions, and ensuring connections between theory and practice. This learner-centered method emphasized critical thinking, creativity, teamwork, and real-life application of knowledge, enabling students to construct deeper and more meaningful understanding of electrical energy and electronics concepts.

3.8.3 Post-Intervention

Post-Intervention Activities

Following the six-week intervention, a post-intervention phase was conducted to assess the effect of problem-based learning (PBL) and traditional lecture-based teaching on students' academic performance, science process skills, and perceptions. This phase included both quantitative and qualitative data collection methods. Post-intervention quantitative data was collected with SSAT and SPSAT post-test, and Likert type questionnaire. Qualitative data was collected using interview guide.

After the intervention, both the experimental group and the control group sat for a post-test that was similar to the pre-test. The test had two parts: the Science Achievement Test (SSAT), which contained 20 multiple-choice questions worth 20 marks, and the Science Process Skills Achievement Test (SPSAT), which included 10 practical–theoretical questions, each carrying two marks, also summing up to 20 marks. The questions were carefully drawn from the SHS Integrated Science syllabus on electrical energy and electronics to ensure fairness and consistency. Students were given 60 minutes to complete the test under examination conditions. Their responses were marked using clear rubrics, making sure scoring was fair and objective. The results provided a direct way to see how much progress each group had made and to compare the effectiveness of the two teaching approaches.

To further explore student experiences with PBL, a 5-point Likert scale questionnaire was administered to the experimental group. The questionnaire, consisting of 10 closed-ended items, assessed students' perception of PBL. Responses were collected and analysed to identify trends in student perceptions.

Additionally, structured interviews were administered to students in the Experimental Group to gather qualitative data to augment the Likert scale questionnaire. Responses from the interviews were analysed thematically to answer the research question on students' perception on PBL.

3.9 Data Analysis Techniques

Data Analysis is the process of systematically applying statistical and/or logical techniques to describe and illustrate, condense and recap, and evaluate data. The purpose of analysing data is to obtain useful information. The analysis, irrespective of whether the data is qualitative or quantitative, may describe and summarise the data, identify relationships between variables, compare variable, identify the difference between variables and forecast outcomes. The data obtained from the learners through the pre-intervention and post-intervention test, questionnaires and interview guides were organised and summarised to obtain a general sense of information and to reflect on its overall meaning from the research. Statistical package for social sciences (SPSS) version 27 was used to analyse the data on students' acquisition of some selected science process skills, academic performance and perceptions into frequencies, percentages and means. Independent samples t-test statistic was used to analyse the significant difference between the science process skills of the participants in the experimental and control groups before and after the intervention.

Independent samples t-test was used to analyse the differential effect of problem-based learning on male and female students' science process skills acquisition. T-test was also used to assess the effect of gender on academic performance between the control group and the experimental group.

3.10 Ethical Considerations

Ethical considerations are central to ensuring integrity and credibility in research, as they guide researchers in distinguishing between right and wrong (Burgess, 2019). Gray (2019) stressed the necessity of adhering to ethical standards when conducting educational research and this study strictly observed such principles. The researcher remained objective throughout the discussions and analysis of findings, while all works of other scholars consulted were properly acknowledged using the APA referencing style.

Before the commencement of the study, permission was sought from the school authorities, and participants were fully briefed on the purpose of the research and their rights as respondents. Participation was entirely voluntary, and learners were informed of their right to withdraw from the study at any stage without any consequences. The study also prioritised the protection of participants' privacy, anonymity, and dignity. All data collected were treated with strict confidentiality. Above all, the researcher ensured that no respondent experienced harm or abuse in any form throughout the research process.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter focuses on results and discussion of findings of the results from the data collected for the study. Both descriptive and inferential analyses were employed in analysing the collected data. Mean, standard deviations and two tailed independent sample t-test were used to analyse the findings and present the results. The interpretation and discussion of the results presented in this chapter are based on the research questions of the study.

4.1.1 Research question one: What is the influence of problem-based learning on students' acquisition of science process skills in the study of electrical energy and electronics in integrated science?

The purpose of this research question is to determine how the PBL approach influences students' five science process skills over a period.

To answer this research question, students' performances in five science process skills; observation, measurement, inferring, predicting, and classifying were monitored weekly for six weeks. The mean scores and standard deviations for each skill at each time point are presented in Table 1.

Table 1: Mean Scores and Standard Deviations of Students' Science Process Skills

Process Skill	Week 1 (M±SD)	Week 2 (M±SD)	Week 3 (M±SD)	Week 4 (M±SD)	Week 5 (M±SD)	Week 6 (M±SD)
Observation	2.30 ± 0.70	2.50 ± 0.68	2.78 ± 0.71	2.84 ± 0.70	2.91 ± 0.72	2.98 ± 0.72
Measurement	2.40 ± 0.72	2.60 ± 0.70	2.91 ± 0.75	2.94 ± 0.73	2.98 ± 0.76	3.20 ± 0.55
Inferring	2.10 ± 0.65	2.35 ± 0.69	2.60 ± 0.73	2.66 ± 0.69	2.74 ± 0.70	2.82 ± 0.70
Predicting	2.20 ± 0.66	2.45 ± 0.67	2.68 ± 0.72	2.73 ± 0.71	2.80 ± 0.73	2.87 ± 0.73
Classifying	2.35 ± 0.68	2.55 ± 0.69	2.79 ± 0.70	2.83 ± 0.69	2.89 ± 0.72	2.95 ± 0.72

M = mean; *SD* = standard deviation; maximum possible score = 4.

The results presented in Table 1 indicate that observation skills began mean value M = 2.30 (SD = 0.70) in Week 1, increased to M = 2.50 (SD = 0.68) in Week 2, and rose further to M = 2.78 (SD = 0.71) in Week 3. The progression continued through Week 4 (M = 2.84, SD = 0.70) and Week 6 (M = 2.98, SD = 0.72). The pattern shows consistent, incremental growth week after week. This confirms that repeated engagement in problem-based tasks gradually sharpened students' ability to notice details, distinguish relevant from irrelevant features, and record accurate data.

Measurement started higher than most other skills at M = 2.40 (SD = 0.72) in Week 1 and increased to M = 2.60 (SD = 0.70) in Week 2. By Week 3, the mean jumped to M = 2.91 (SD = 0.75), and further small gains were recorded in Week 4 (M = 2.94, SD = 0.73) and

Week 6 (M = 3.20, SD = 0.55). This shows that while growth in the first two weeks was gradual, a sharper rise was observed from Week 3 to week 6.

Inferring skills among students started at the lowest point, M = 2.10 (SD = 0.65) in Week 1, but improved to M = 2.35 (SD = 0.69) in Week 2. The skill continued to rise in Week 3 (M = 2.60, SD = 0.73), Week 4 (M = 2.66, SD = 0.69), and Week 6 (M = 2.82, SD = 0.70). The week-to-week pattern reflects gradual, consistent growth without dramatic jumps. Despite the improvement in students inferring skills over the five weeks, this skill recorded the least means cores over the period.

Predicting began at M = 2.20 (SD = 0.66) in Week 1 and rose to M = 2.45 (SD = 0.67) in Week 2. It increased further to M = 2.68 (SD = 0.72) in Week 3, followed by smaller increments in Week 4 (M = 2.73, SD = 0.71) and Week 6 (M = 2.87, SD = 0.73). The steady growth suggests that students' ability to anticipate outcomes improved gradually as their conceptual understanding deepened. The early low scores reflect weak predictive confidence, but as observational and inferential skills improved, prediction also strengthened.

Classifying improved from M = 2.35 (SD = 0.68) in Week 1 to M = 2.55 (SD = 0.69) in Week 2. Week 3 showed further growth (M = 2.79, SD = 0.70), followed by smaller increases in Week 4 (M = 2.83, SD = 0.69) and Week 6 (M = 2.95, SD = 0.72). This indicates that students gradually became more competent in grouping, comparing, and organising data. Classification growth was most visible between Weeks 2 and 3, suggesting that once students developed basic observational skills, they could apply them to identify similarities and differences more effectively.

Additionally, independent samples t-test including the means and standard deviations of pre-test and post-test of students' science process skills scores in the control and experimental groups were computed and presented in Table 2 below.

Table 2: Independent samples t-test results on pre-test for control and experimental groups on students' science process skills acquisition

Group	Test	N	Mean	S.D	Mean difference	t-value	Df	Sig. (2-tailed)
Experimental group	Pre-test	49	2.41	1.38				
					0.22	0.62	93	0.54
Control group	Pre-test	46	2.22	1.60				

Significant at $P < 0.05$ level of significance cohen's d= 0.13

Table 2 indicates that the mean pre-test score for students' science process skills acquisition in the experimental group is 2.41 with a standard deviation of 1.38 while the mean pre-test score for students' science process skills acquisition in the control group is 2.22 with a standard deviation of 1.60. The calculated mean difference of 0.22 suggests that the pre-test scores for both groups were highly homogenous. The t-value of 0.62, with 93 degrees of freedom, indicates that the difference between the pre-test and post-test scores was not only substantial but also statistically robust. Furthermore, the p-value of 0.54, which is greater than the significance level of 0.05, confirms that the observed similarity was statistically insignificant and unlikely to have occurred by chance. The effect size of 0.13 indicates that the pre-test score difference between the two groups was very small had no practical significance on the post-test scores.

Table 3: Independent samples t-test results on post-test for control and experimental groups on students' science process skills acquisition

Group	Test	N	Mean	S.D	Mean difference
Experimental group	Post-test	49	10.71	2.76	
					2.15
Control group	Post-test	46	8.57	2.17	

In table 3, the post-test score on students' science process skills acquisition revealed that the mean score for students in the experimental group was 10.71 with a standard deviation of 2.76 while the mean score for the control group was 8.57 with a standard deviation of 2.17. Also, the calculated mean difference between the two groups was 2.15

The pre-test and post-test scores of students in the control group indicate that there was an improvement in the mean score of the pre-test results from 2.22 to post-test score of 8.57. Even though there was an improvement in the performance of students taught with traditional lecture method, the relatively large mean difference of 2.15 suggests a positive effect of problem-based learning on the science process skills acquisition of SHS students in in Electrical Energy and Electronics in Integrated Science concepts.

To testing null hypothesis H_{01}: There is no statistically significant effect of problem-based learning on the acquisition of some selected process skills among students in Electrical Energy and Electronics, a comparative sample t-test was used to test null hypothesis (H_{01}) using post-test scores of students in the control and experimental groups. The result of the analysis is presented in Table 4.

Table 4: Summary of Independent samples t-test results Analysis on post-test for control and experimental groups on students' science process skills acquisition

Group	Test	N	Mean	S.D	t-value	Df	Sig. (2-tailed)
Experimental group	Post-test	49	10.71	2.76			
					4.21	93	0.01
Control group	Post-test	46	8.57	2.17			

Significant at P < 0.05 level of significance cohen's d= 0.86

Table 4 shows a calculated t-value of 4.21 and a corresponding P-value of 0.01 observed at 93 degrees of freedom. The P-value of 0.01 is less than the chosen significance level (alpha value) of 0.05, hence null hypothesis is rejected. This means that there is statistically significant difference between the mean science process skills acquisition of SHS students after being taught with problem-based learning method.

4.1.2 Research question two: To what extent does problem-based learning affect students' academic performance in the study of electrical energy and electronics in integrated science?

The purpose of this research question is to assess the extent to which problem-based learning (PBL) affects students' academic performance in Electrical Energy and Electronics within Integrated Science. To address it, pre-test and post-test scores from the experimental (PBL) and control (lecture) groups were analysed by computing means, standard deviations, and mean differences, with the results presented in Table 5.

Table 5: Independent samples t-test results on pre-test for control and experimental groups on students' academic performance

Group	Test	N	Mean	S.D	Mean difference	t-value	Df	Sig. (2-tailed)
Experimental group	Pre-test	49	2.57	0.89	0.22	0.23	93	0.66
Control group	Pre-test	46	2.52	1.24				

Not Significant at P < 0.05 level of significance cohen's d= 0.05

The control group's mean pre-test score was 2.52 with a standard deviation of 1.24, whereas the experimental group's mean score was 2.57 with a standard deviation of 0.89. Additionally, a mean difference of 0.22 was computed between the Experimental and Control groups. The experimental and control groups' pre-test scores did not differ statistically significantly, as indicated by the p-value of 0.66. This implies that the experimental and control groups' pre-test results on the students' academic performance in the study of electrical energy and electronics in integrated science concepts were similar.

Table 6: independent samples t-test results on post-test for control and experimental groups on students' academic performance

Group	Test	N	Mean	S.D	Mean difference
Experimental group	Post-test	49	11.35	2.57	3.22
Control group	Post-test	46	8.13	2.32	

The mean score on the post-test for the Experimental group was 11.35, with a standard deviation of 2.57 while the mean post-test score for the Control group was 8.13, with a standard deviation of 2.32. Also, the calculated mean difference between the Experimental group and Control group was 3.22. The mean difference of 3.22 suggests a positive effect of problem-based learning instruction on the academic performance of SHS students in the study of electrical energy and electronics in integrated science concepts. The standard deviations suggest that although students started with a uniform low performance (SD = 0.89 and 1.24) for the experimental group and Control group, their outcomes became more varied post-intervention (SD = 2.57 and 2.32) for experimental group and Control group respectively. The results indicate an improvement in academic performance from students in the Experimental group, suggesting that problem-based has a positive effect on the academic performance of SHS students in selected Integrated Science concepts.

To test the null hypothesis H_{02}: There is no statistically significant effect of problem-based learning on academic performance of students in electrical energy and electronics, an independent sample t-test was used to test null hypothesis ($H_{01)}$ using post-test scores of students in the control and experimental groups. The result of the analysis is presented in Table 7.

Table 7: Summary of independent samples t-test analysis of post test score of on academic performance between Experimental group and Control groups.

Group	Test	N	Mean	S.D	t-value	Df	Sig. (2-tailed)
Experimental group	Post-test	49	11.36	2.57			
					6.38	93	0.00
Control group	Post-test	46	8.13	2.32			

Significant at P < 0.05 level of significance cohen's d= 1.32

Table 7 displays the calculated t-value of 6.38 and corresponding 93-degree-of-freedom P-value of 0.00. As the selected significance level (alpha value) of 0.05 is greater than the P-value of 0.00, the null hypothesis is rejected. The utilization of problem-based learning instruction in the teaching and learning of electricity and electronics in Integrated Science is responsible for the statistically significant difference in the mean academic performance of students in the Experimental group compared to the Control groups. Even though there is statistically significant difference between the mean academic performance in pre-test and post test scores of students taught using the traditional lecture method (control group), the intervention in the experimental group (problem-based learning), brought more significant improvement in the academic performance of the students in the selected Integrated Science concepts.

4.1.3 Research question three: What is the difference in academic performance between female and male students in the study of electrical energy and electronics in Integrated Science?

The purpose of this research question is to examine gender differences in academic performance in Electrical Energy and Electronics within Integrated Science. To address it, post-test scores for male and female students were compared by computing means, standard deviations, and the mean difference, with the descriptive results presented in Table 8.

Table 8: Independent samples t-test results on post-test for control and experimental groups on students' academic performance

Group	Test	N	Mean	S.D	Mean difference
Male	Post-test	23	10.08	2.74	
					0.49
Female	Post-test	26	9.59	3.06	

Table 8 presents the descriptive statistics for the post-test scores of male and female students, highlighting the mean scores, standard deviations, and mean difference between the two groups. From the data, it is observed that male students (N = 23) recorded a mean score of 10.08 with a standard deviation of 2.74, while female students (N = 26) had a mean score of 9.59 with a standard deviation of 3.06. This results in a mean difference of 0.49 in favour of the male students. The higher mean score among the male group suggests a slightly better academic performance compared to their female counterparts. However, the relatively small size of the mean difference (0.49) and the overlapping standard deviations indicate that this difference may not be substantial. The higher standard deviation among female students also suggests slightly more variability in their scores, indicating that while some females performed very well, others may have performed lower than average.

To test null hypothesis H_3: There is no significant difference in academic performance between female and male students in the study of electrical energy and electronics in Integrated Science, post-test scores of male and female students in the experimental group were subjected to t-test statistics. A summary of the analysis is presented in Table 9 below

Table 9: Summary of independent samples t-test analysis of post test score on academic performance males and females in the Experimental group.

Group	Test	N	Mean	S.D	t-value	Df	Sig. (2-tailed)
Male	Posttest	23	10.08	2.74			
					0.80	93	0.43
Female	Posttest	26	9.59	3.06			

Not significant at P < 0.05 level of significance cohen's d= 0.17

Table 9 presents the results of the independent samples t-test conducted to determine whether the observed difference in post-test academic performance between male and female students was statistically significant. As shown in the table, male students (N = 23) had a post-test mean score of 10.08 with a standard deviation of 2.74, while female students (N = 26) had a mean score of 9.59 with a standard deviation of 3.06. The t-test analysis yielded a t-value of 0.80 with 93 degrees of freedom and a p-value of 0.43 (two-tailed). Since the p-value is greater than the conventional significance level of 0.05, the result is not statistically significant. This implies that the observed mean difference of 0.49 between male and female students could have occurred by chance, and there is no sufficient evidence to conclude that gender had a significant influence on students' academic performance following the instructional intervention. Therefore, the null hypothesis stating that there is no significant difference in post-test performance between the two groups is retained.

4.1.4 Research question four: What are the perceptions of students on the use of problem-based learning in integrated science lessons?

The purpose of this research question is to examine students' perceptions of PBL in Integrated Science. To address it, a Likert-scale questionnaire captured views on conceptual understanding, practical skills, collaboration, confidence, real-world relevance, research skills, motivation, teamwork, and overall satisfaction. Frequencies and percentages were computed for each item, and student comments were reviewed to enrich interpretation. The summary of responses is presented in Table 10.

Table 10: Students' Responses to Questionnaire on their perception regarding problem-based learning method

Item	Response type				
	SD	D	U	A	SA
1. Solving problems during lesson has enhanced my understanding of electrical energy and electronics concepts.	0 (0.0%)	1 (2.0%)	7 (14.3%)	22 (44.9%)	19 (38.8%)
2. Engaging in lessons involve solving problems has improved my practical skills in electrical circuits and electronic devices.	3 (6.1%)	1 (2.0%)	4 (8.2%)	19 (38.8%)	22 (44.9%)
3. Working with peers during lessons in solving problems has enhanced my abilities to solve simple problem in electrical engineering scenarios.	1 (2.0%)	1 (2.0%)	5 (10.2%)	21 (42.9%)	21 (42.9%)
4. The lesson has increased my confidence in designing and analyzing simple electrical and electronic systems.	0 (0.0%)	1 (2.0%)	4 (8.2%)	22 (44.9%)	22 (44.9%)
5. The real-world problems addressed in the lessons have made learning electrical energy and electronics more engaging.	1 (2.0%)	1 (2.0%)	7 (14.3%)	21 (42.9%)	19 (38.8%)
6. Through the lessons, I have developed better research skills especially in electrical energy and electronics topics.	1 (2.0%)	0 (0.0%)	3 (6.1%)	26 (53.1%)	19 (38.8%)
7. The lessons have helped me connect theoretical knowledge of electrical energy and electronics to practical applications.	2 (4.1%)	0 (0.0%)	3 (6.1%)	24 (49.0%)	20 (40.8%)
8. I am more motivated to learn about electrical energy and electronics through solving problems compared to the old teaching methods that our teacher use.	1 (2.0%)	1 (2.0%)	5 (10.2%)	25 (51.0%)	17 (34.7%)
9. Solving problems during the lessons have improved my ability to work effectively in group	1 (2.0%)	2 (4.1%)	4 (8.2%)	24 (49.0%)	18 (36.7%)
10. Overall, I am satisfied with my learning experience in electrical energy and electronics through solving problem.	1 (2.0%)	3 (6.1%)	6 (12.3%)	25 (50.9%)	14 (28.6%)

Table 10 reveals that, SHS students have positive perceptions of the problem-solving approach adopted during the instruction in the teaching and learning of electricity and electronics in Integrated Science.

In response to the first item, "Solving problems during lessons has enhanced my understanding of electrical energy and electronics concepts", a total of 41 students agreed, 22 students (44.9%) selected "Agree," while 19 (38.8%) chose "Strongly Agree." Only 1 student (2.0%) disagreed, and 7 (14.3%) remained neutral. This indicates that the majority of students perceived a strong improvement in their conceptual understanding due to the problem-solving method.

In the second item, which explored practical skill development, 41 students (83.7%) again responded positively. Specifically, 22 students (44.9%) strongly agreed and 19 (38.8%) agreed that their practical skills in electrical circuits and electronic devices had improved. Only 3 students (6.1%) strongly disagreed, 1 (2.0%) disagreed, and 4 (8.2%) were neutral. These results emphasise the effectiveness of the lessons in enhancing hands-on technical competencies among students.

On the third item, concerning collaborative learning, a combined 42 students (85.8%) agreed that working with peers during problem-solving lessons enhanced their ability to solve simple electrical engineering problems. Of these, 21 students (42.9%) agreed and another 21 (42.9%) strongly agreed. Only 1 student each (2.0%) selected "Strongly Disagree" and "Disagree," while 5 students (10.2%) were neutral. This suggests that collaborative tasks were well-received and contributed meaningfully to students' problem-solving development.

Confidence in designing and analysing systems, the focus of item four, also saw highly favorable responses. An equal number of students, 22 (44.9%) each chose “Agree” and “Strongly Agree,” with only 1 student (2.0%) marking “Disagree” and 4 students (8.2%) remaining neutral. No students selected “Strongly Disagree.” These findings demonstrate that the instructional approach significantly boosted students’ confidence.

Regarding student engagement through real-world applications (item five), 21 students (42.9%) agreed and 19 (38.8%) strongly agreed that the lessons were more engaging because they involved real-life problem scenarios. Just 1 student each (2.0%) disagreed and strongly disagreed, while 7 (14.3%) were neutral. This indicates that real-world contexts made the learning process more interesting and meaningful for most students.

The sixth item revealed that students developed better research skills through the lessons. A total of 45 students (91.9%) expressed agreement, 26 (53.1%) agreed and 19 (38.8%) strongly agreed while only 3 students (6.1%) remained neutral. One student (2.0%) strongly disagreed, and none disagreed, reinforcing the idea that the instructional model supported inquiry-based learning and independent exploration.

Item seven focused on the ability to connect theory to practice. Here, 44 students (89.8%) responded positively, with 24 students (49.0%) agreeing and 20 (40.8%) strongly agreeing. Only 3 students (6.1%) were neutral, and 2 (4.1%) strongly disagreed.

Student motivation, addressed in item eight, also received strong support. Twenty-five students (51.0%) agreed, and 17 (34.7%) strongly agreed that they were more motivated to learn under this method compared to traditional teaching. Only 1 student each (2.0%) strongly disagreed and disagreed, and 5 students (10.2%) were neutral.

In item nine, which examined teamwork, 24 students (49.0%) agreed and 18 (36.7%) strongly agreed that solving problems during lessons improved their ability to work in groups. Four students (8.2%) were neutral, while just 2 (4.1%) disagreed and 1 (2.0%) strongly disagreed. This supports the idea that collaborative learning environments can foster important interpersonal and group problem-solving skills.

Finally, regarding overall satisfaction (item ten), 25 students (50.9%) agreed and 14 (28.6%) strongly agreed that they were satisfied with their learning experience through problem-solving. A total of 6 students (12.3%) were neutral, 3 (6.1%) disagreed, and 1 (2.0%) strongly disagreed. Although slightly lower than other items, this still represents a substantial level of student approval for the overall instructional approach.

4.1.5 Students interview response

The findings of the study based on interview data collected from students who participated in the instruction in electrical energy and electronics. The responses provide insights into students' perceptions about problem-based learning, its effect on their learning experiences, and the skills they developed. The findings are presented thematically as follow.

Students' Initial Reactions to the Problem-Solving Approach: When students were first introduced to the problem-solving approach, their reactions varied. Some described it as exciting and new, while others initially found it challenging or unfamiliar.

Some of the participants indicated that *"At first, I didn't understand why we had to solve problems instead of just taking notes, but it became more interesting as we started building circuits ourselves."*

"I was afraid because I wasn't sure I could solve the problems, but after a few lessons, I liked it better than the other one."

"I was surprised. It was the first time we worked in groups and used real wires and batteries."

Examples of Problem-Solving Activities: Students described several practical activities that involved hands-on problem solving. These included designing circuits, testing voltage, and applying safety procedures during experimentation.

"We had to connect a series circuit that would light two bulbs and calculate the total resistance."

"One time we were given a faulty circuit and had to find where the break was."

"We had to solve a problem about why a bulb wouldn't turn on in a parallel circuit and fix it."

Influence on Conceptual Understanding: Many students indicated that the problem-solving tasks improved their understanding of electrical concepts. They emphasised that learning became clearer when they had to apply the knowledge themselves.

"I now know the difference between current and voltage because I saw how they behave in a circuit we built."

"The formulas made more sense when I used them to find the resistance in real circuits."

"I remember things better now because I understand how they work, not just the definitions."

Enhancement of Practical Skills: Students widely agreed that the problem-solving approach significantly improved their hands-on skills. They described feeling more

confident in using laboratory tools and assembling circuits. Some students indicated that *"Before, I didn't even know how to strip wires. Now I can set up a full circuit without help."*
"I've learned how to use a multimeter and connect resistors properly."
"Now I can fix small electrical faults at home, like changing plugs and checking fuses."

Collaboration and Peer Learning: Working in groups was a key component of the approach. Students reported that collaboration allowed them to learn from each other and find better solutions together.

"I didn't know how to measure current, but my group members showed me, and I taught them how to connect batteries."
"We solved problems faster when we shared ideas."
"Group work helped me understand better because we explained things to each other in simple ways."

Communication and Expression: Students mentioned improvements in communication, particularly in their ability to explain concepts and contribute to discussions.

"I used to be shy, but now I can present my solution to the whole class."
"I've learned how to explain my ideas clearly to others."
"It helped me learn new words related to electricity and how to use them correctly."

Application of Theoretical Knowledge to Practice: Several students cited examples of how problem-solving helped them connect theoretical lessons to real-life situations.

"When we talked about short circuits in class, I didn't understand. But when we caused one by mistake during an activity and saw the spark, I got it."

"Learning about Ohm's Law was confusing until we used it in a real circuit and got the same values as the calculations."

"Now I know how the things we learn are used in real life, like how current flows in wires in our homes."

Motivation and Engagement: The majority of students said the problem-solving approach made learning more interesting and enjoyable compared to traditional teaching.

"I pay more attention because I know I will have to solve something, not just listen."

"I now enjoy the subject. It feels like we're doing science, not just reading about it."

"I feel proud when I get something to work, like lighting a bulb or fixing a problem."

Relevance of Real-World Problems: Students appreciated the real-life relevance of the problems presented in class, stating that it made learning more purposeful.

"We worked on a problem about wiring a simple room, which I know will help me in life."

"The problems we solved were like things electricians do, so it feels useful."

"Now I understand why we learn these topics, not just for exams but for everyday use."

Challenges Faced During Problem-Solving: While the experience was largely positive, students acknowledged some challenges.

"Sometimes the group work was not fair, some people did all the work."

"We didn't always have enough tools, so we had to wait or share."

"Some problems were too difficult, and we didn't have enough time to finish."

Suggestions for Improvement: Students offered suggestions to enhance the implementation of the problem-solving method.

"Provide more equipment so that every group can work at the same time."
"The teacher should monitor group work better to make sure everyone contributes."
"We should be given more time to work on the harder problems."

Overall Satisfaction and Recommendations: Students overwhelmingly expressed satisfaction with the learning experience and recommended that the approach be used more broadly in science education.

"I learned more in these six weeks than in the whole last term."
"I would like all science teachers to use this method because it helps us understand and enjoy learning."
"It should be used in other topics, not just this one."

4.2 Discussion of Findings

The discussion of the findings is done under the four main themes that guide this study. These include influence of problem-based learning on students' acquisition of science process skills in the study of electrical energy and electronics in integrated science, effect of problem-based learning on students' academic performance in the study of electrical energy and electronics in integrated science, academic performance differential between female and male students in the study of electrical energy and electronics in integrated science and perceptions of students on the use of problem-based learning in integrated science lessons.

4.2.1 Influence of problem-based learning on students' acquisition of science process skills in the study of electrical energy and electronics in integrated science.

The results revealed that observation skills improved steadily from 2.30 in Week 1 to 2.98 in Week 6 (overall gain of +0.68, approximately +29.6%). The early-phase mean for Weeks 1–2 was 2.40, rising to 2.88 across Weeks 3–6. The largest single-step gain occurred from Week 2 to Week 3 (+0.28), followed by smaller but consistent increases from Week 4 to Week 5 (+0.07) and from Week 5 to Week 6 (+0.07). These incremental gains indicate quick attention to relevant features and more accurate recording. The findings of this study indicate that observation plays a pivotal role in shaping learners' engagement with science activities. This aligns with Sarı et al. (2020), who showed that STEM activities in a simulation-based inquiry environment significantly improved students' scientific process skills and STEM awareness, reinforcing the central role of basic process skills in inquiry. The results also echo the conclusions of Ainun and Jefriyanto (2023), who found that using hands-on teaching aids and laboratory activities makes learning more active and engaging and improves students' science process skills

Measurement strengthened from 2.40 in Week 1 to 3.20 in Week 6 (change +0.80, approximately +33.3%). The early mean for Weeks 1–2 was 2.50, increasing to 2.94 across Weeks 3–5 and peaking in Week 6. The mid-cycle surge was strongest from Week 2 to Week 3 (+0.31), followed by modest gains from Week 3 to Week 5 (+0.03 and +0.04) and a larger late-cycle increase from Week 5 to Week 6 (+0.22). This pattern suggests rapid consolidation of unit sense and instrument handling by mid-intervention, followed by marginal refinements. It aligns with Safaah et al. (2017) and Zhang and Ma (2023) on the need for extended practice, and confirms Yeboah et al., (2017) that resource constraints can moderate short-term growth in Ghanaian labs.

Inferring rose from 2.10 in Week 1 to 2.82 in Week 6 (change +0.72, approximately +34.3%), representing the largest proportional gain. The early mean for Weeks 1–2 was 2.23, increasing to 2.66 in Week 4 and 2.82 in Week 6. The most pronounced jump occurred from Week 2 to Week 3 (2.35 to 2.60, +0.25), followed by smaller, steady gains from Week 3 to Week 4 (+0.06) and from Week 4 to Week 6 (+0.16). Growth from this lower baseline indicates a strengthening ability to link evidence to warranted conclusions.

This aligns with the assertion of Nadalini et al., (2025) that inferencing, which is a higher-order skill, develops more gradually and confirms MoE (2019) priorities for scientific reasoning.

Predicting increased from 2.20 in Week 1 to 2.87 in Week 6 (change +0.67, approximately +30.5%). The early mean for Weeks 1–2 was 2.33, rising to 2.80 across Weeks 4–6. Gains were front-loaded (Week 1 to Week 2: 2.20 to 2.45, +0.25; Week 2 to Week 3: 2.45 to 2.68, +0.23) and more gradual thereafter, with a smaller rise from Week 3 to Week 4 (2.68 to 2.73, +0.05) and a modest cumulative gain from Week 4 to Week 6 (2.73 to 2.87, +0.14) suggesting consolidation. This supports Deutscher et al. (2021) showing PBL advantages over lecture method on prediction tasks, and confirms the dependence of prediction on earlier growth in observation and inference.

Classifying improved from 2.35 in Week 1 to 2.95 in Week 6 (change +0.60, approximately +25.5%). The mean for Weeks 1–2 was 2.45, increasing to 2.87 across Weeks 3–6. The largest single increase occurred from Week 2 to Week 3 (2.55 to 2.79,

+0.24), while later gains were smaller, with a modest rise from Week 3 to Week 4 (+0.04) and a cumulative increase from Week 4 to Week 6 (2.83 to 2.95, +0.12). As observational competence firmed up, students became better at grouping, comparing, and organising data. This aligns with Sarı et al. (2020) that classification strengthens when learners manage multiple variables, supports Ainun and Jefriyanto (2023) on the role of collaboration in sharpening categorisation, and confirms NaCCA (2019) that classifying is central to scientific literacy.

To further ascertain the effect of PBL on science process skills acquisition, a t-test analysis was run between score from the experimental and control groups

The pre-test results establish strong baseline equivalence between the two groups. The experimental group (n = 49) averaged 2.41 (SD = 1.38) and the control group (n = 46) averaged 2.22 (SD = 1.60), yielding a mean difference of 0.22. This difference was not statistically significant, $t(93) = 0.62$, $p = 0.54$. This confirms that the two groups were statistically comparable prior to the intervention since any subsequent group differences can be attributed to the intervention rather than pre-existing disparities. This aligns with Creswell and Creswell (2017) and supports Roberts et al. (2022) on the importance of establishing group homogeneity in experimental studies.

Following the intervention, clear performance differences emerged in favour of the PBL condition. The experimental group obtained a post-test mean of 10.71 (SD = 2.76), whereas the control group scored 8.57 (SD = 2.17), a mean difference of 2.15. An independent-samples *t*-test showed this advantage to be statistically significant, $t(93) = 4.21$, $p = .01$, leading to rejection of the null hypothesis at $\alpha = .05$. Both groups improved over time, but the experimental group's gain of approximately +8.30 points exceeded the control group's +6.35. These results support the findings of Ainun and Jefriyanto, (2023) that real-life problem contexts and collaborative inquiry promote learners' observing, classifying, predicting, measuring, and related skills. The trend also supports Duha and Kaur (2023) and Roberts et al. (2022), who documented how PBL shifts classrooms toward student-led investigation, increasing autonomy and deepening reasoning. The findings also confirm that of Sarı, et al. (2020), who link hypothesising, testing, and explaining to improved predictive and analytical performance. Finally, comparable findings reported by Appiah-Twumasi et al. (2024) also support the problem-centred approaches over lecture methods in the teaching of Integrated Science in Ghanaian schools.

The improvement observed in the control group (from 2.22 to 8.57) confirms that traditional instruction can raise basic attainment; however, its smaller magnitude relative to the PBL condition supports critiques that teacher-centred methods under-serve higher-order reasoning and sustained inquiry (Zhang & Ma, 2023). By contrast, inquiry-driven practical work aligns with Apeadido et al. (2024), supporting stronger SPS and achievement outcomes.

4.2.2 Effect of problem-based learning on students' academic performance in the study of electrical energy and electronics in integrated science

The pre-test analysis establishes baseline equivalence between the groups and strengthens the internal validity of subsequent inferences. As shown in Table 5, the experimental group (n = 49) recorded a mean of 2.57 (SD = 0.89), while the control group (n = 46) recorded 2.52 (SD = 1.24), a mean difference of 0.22 that was not statistically significant (t(93) = 0.23, p = .66). This confirms that the groups were statistically comparable before instruction and supports attributing any post-test differences to the intervention rather than pre-existing disparities (Creswell & Creswell, 2017; Roberts et al., 2022). The uniformly low pre-test means also mirror widely reported challenges in Ghanaian SHS science performance, often linked to teacher-centred pedagogy and constrained laboratory exposure (Appiah-Twumasi et al., 2024; Apeadido et al., 2024).

Following the intervention, clear post-test differences emerged in favour of problem-based learning (PBL). As reported in Table 6, the experimental group attained 11.35 (SD = 2.57) compared with 8.13 (SD = 2.32) for the control group, a mean difference of 3.22. The inferential test in Table 7 indicates that this gap was statistically significant ($t(93) = 6.38$, $p < .001$), leading to rejection of H_{02} at $\alpha = 0.05$ and indicating that PBL produced better results in Electrical Energy and Electronics. Both groups improved over time, but the magnitude of improvement was greater for the experimental group, showing a positive and differential effect of the PBL approach. Variability also increased from pre- to post-test (experimental SD: 0.89 to 2.57; control SD: 1.24 to 2.32), suggesting broader differentiation in performance as assessments demanded more complex application.

The significant difference between the experimental and control groups also confirms Abugbilla (2023) and Usman et al., (2023) who reported that in Ghana the PBL approach significantly impacted students' performance and underscored that traditional teacher-centred approaches were contributing to lower performance.

echoes the position of NaCCA (2019) and the (MoE, 2019), which advocate for learner-centered, inquiry-based approaches as part of Ghana's standards-based curriculum reforms. The modest gains observed in the control group highlight the limitations of lecture-driven instruction, which Zhang and Ma (2023) noted provides content coverage but fails to promote deep cognitive engagement.

The post-test analysis provides compelling evidence that PBL is superior to lecture-based methods in improving academic performance. By situating students in problem-solving contexts that demand critical thinking, collaboration, and application, PBL equips learners with the skills and knowledge needed to succeed in Integrated Science. The rejection of H_{02} is therefore both statistically validated and theoretically grounded, demonstrating that PBL is not only effective for science process skills but also for raising overall academic achievement among SHS students.

Despite the benefits of PBL, students identified challenges with it. Some noted unequal participation, saying, "Sometimes the group work was not fair, some people did all the work and some were just sitting and watching." Others mentioned limited resources, "We didn't always have enough tools, so we had to wait or share," while time constraints were also a concern: "Some problems were too difficult, and we didn't have enough time to finish." These issues echo Takyi et al., (2019) who reported that resource shortages and uneven participation often limit inquiry-based learning.

4.2.3 Academic performance differential between female and male students in the study of electrical energy and electronics in Integrated Science

The gender analysis explored whether post-test academic performance differed between male and female students after exposure to problem-based learning (PBL) in Electrical Energy and Electronics. As reported in Table 8, male students (n = 23) obtained a mean post-test score of 10.08 (SD = 2.74), while female students (n = 26) recorded 9.59 (SD =

3.06), yielding a modest mean difference of 0.49 in favour of males. The overlapping standard deviations, particularly the larger dispersion in the scores among females suggest within-group variability. The observed mean difference is small between the two groups. The lower end of the female score distribution could be attributed to Gender Schema Theory (Bem, 1981) which suggested that such patterns can be shaped by cultural messages that push girls away from disciplines socially labelled as 'male reserve', like electronics electricity and electronics.

To determine whether this pattern reflected a reliable difference, an independent-samples *t*-test was conducted on the experimental group (see Table 9). Male students (n = 23; M = 10.08, SD = 2.74) were compared with female students (n = 26; M = 9.59, SD = 3.06). The analysis yielded t (93) = 0.80, p = 0.43, indicating no statistically significant difference between the groups at α =0.05 level. On this basis, H_{03} is retained: the observed mean gap could be attributed to sampling variability rather than a systematic gender effect. Overall, the descriptive and inferential results point to gender parity in post-intervention academic performance under PBL.

This finding aligns with Sakyi-Hagan & Hanson, (2022) who reported that there no gender gap in pre-service integrated science teachers' achievement, underscoring that when given equal learning opportunities, female performance matches male performance. The finding also corroborates the work of Ajai & Imoko, (2015) that male and female secondary students taught algebra through problem-based learning did not significantly differ in achievement and retention scores, indicating that both genders benefited equally.

Historically, boys have tended to outperform girls in areas like physics and electronics, a trend often attributed to sociocultural expectations and the gendered structuring of science classrooms (UNESCO, 2017; Wrigley-Asante et al., 2023; Britwum et al., 2024; Archer et al., 2013). Yet, Wrigley-Asante et al. (2023) emphasised that such performance gaps are not inherent but socially constructed, and can be significantly narrowed when collaborative and practical learning strategies are implemented. PBL, by its nature, promotes engagement through dialogue, problem-solving, and shared responsibility, making it an effective pedagogical tool for fostering gender equity in science education. These active learning environments encouraged meaningful participation from girls, provided opportunities for group work, and emphasized hands-on experiences that helped female learners internalize concepts more effectively. Such approaches also fostered a sense of belonging in science classrooms, which in turn heightened female students' interest and persistence in scientific learning tasks.

The theoretical explanation for these patterns can be understood through Gender Schema Theory (Bem, 1981), which argues that societal stereotypes and cultural beliefs often channel girls away from male-dominated fields such as electronics and physics. These schemas shape perceptions of who can excel in science, creating barriers for female students. However, instructional models like PBL counteract these stereotypes by positioning both boys and girls as active contributors in supportive, peer-driven environments. Tomas and O'Grady (2016) and Archer et al. (2013) reinforce this perspective, noting that when pedagogical shifts create spaces for collaboration, exploration, and reflection, female students begin to perceive science as an inclusive field in which they can thrive.

Beyond cultural expectations, systemic factors within the classroom also perpetuate gender disparities. Teacher bias and unequal allocation of resources have been documented as hidden contributors to achievement gaps. Britwum et al. (2024) observed that unconscious favoritism toward boys in Ghanaian science classrooms often translates into more encouragement and opportunities for male students, leaving female learners comparatively disadvantaged. In contrast, PBL provides a structure where every student is required to engage actively, thereby reducing opportunities for bias. By creating a balance in classroom participation, PBL ensures that both male and female students feel valued, respected, and empowered to contribute equally.

Overall, the absence of a statistically significant gender difference in this study reinforces the potential of PBL as an equitable instructional approach in science education. Its emphasis on learner autonomy, relevance to real-life contexts, and collaborative problem-solving provides equal opportunities for boys and girls to succeed. This aligns with global and local policy directions: UNESCO (2017) continues to call for gender-responsive teaching in science, and Ghanaian educators are increasingly advocating for approaches that dismantle gender stereotypes and foster inclusivity. By bridging gaps in participation and achievement, PBL stands not only as an effective pedagogy for raising academic performance but also as a powerful tool for advancing gender equity in Ghanaian Senior High School science classrooms.

4.2.4 Perceptions of students on the use of problem-based learning in integrated science lessons.

The results in Table 10 shows that SHS students generally held positive views of the problem-solving approach used in teaching electricity and electronics. For the item

"Solving problems during lessons has enhanced my understanding," 83.7% agreed or strongly agreed (44.9% Agree, 38.8% Strongly Agree), 14.3% were neutral, and 2.0% disagreed, indicating perceived gains in conceptual understanding. Positive ratings on the problem-solving approach are consistent with Juhji and Nuangchalerm (2020), who report that inquiry/problem-solving lessons raise students' motivation and perceived understanding of science concepts. They also align with Roberts et al. (2022), which documents higher student perceptions of autonomy, engagement, and ownership in student-led, inquiry-oriented classrooms

However, when first introduced to the problem-solving approach, students' perceptions ranged from excitement to uncertainty. One student noted, *"At first, I didn't understand why we had to solve problems instead of just taking notes, but it became more interesting as we started building circuits ourselves."* Another admitted, *"I was afraid because I wasn't sure I could solve the problems, but after a few lessons, I liked it better than the other one."* A third added, *"I was surprised. It was the first time we worked in groups and used real wires and batteries."* These statements reflect a shift from initial hesitation to active engagement, a pattern also reported by Liu et al., (2019)

With regards to practical skills acquisition, majority (83.7%) reported improved practical skills in electrical circuits and electronic devices. Only 8.1% disagreed or strongly disagreed, and 8.2% were neutral, indicating a clear perceived gain in hands-on competence. On collaboration, most students (85.8%) felt that working with classmates helped them solve simple electrical circuit problems. Only 2.0% disagreed, suggesting that PBL enhances learners' collaborative skills.

The item on confidence in designing and analysing systems showed most students felt more confident, with 89.8% agreeing, 8.2% neutral, and 2.0% disagreeing. Real-world engagement was well received, as 81.7% agreed lessons tied to real-life problems were more engaging, 14.3% were neutral, and 4.0% disagreed. Research skills improved by students' own report, with 91.9% agreeing, 6.1% neutral, and 2.0% strongly disagreeing.

Linking theory to practice was viewed positively, with 89.8% agreeing they could apply concepts better, 6.1% neutral, and 4.1% strongly disagreeing. One learner explained that, *"I now know the difference between current and voltage because I saw how they behave in a circuit we built,"* while another added, *"The formulas made more sense when I used them to find the resistance in real circuits."* They also highlighted new practical abilities, with one noting, *"Before, I didn't even know how to strip wires. Now I can set up a full circuit without help''.* These results highlight the success of the instructional approach in helping students apply theoretical knowledge in practical contexts. Students reported that PBL deepened their understanding of electrical concepts.

Learners' perception on motivation under PBL was higher, with 85.7% agreeing, 10.2% neutral, and 4.0% disagreeing or strongly disagreeing. Students noted that PBL made lessons more engaging and meaningful. One explained, *"I pay more attention because I know I will have to solve something, not just listen,"* while another added, *"I now enjoy the subject. It feels like we're doing science, not just reading about it."* They also valued the real-world relevance of tasks, with a student observing, *"The problems we solved were like things electricians do, so it feels useful."* These findings suggest that PBL boosted motivation by making learning interactive and practical, a finding consistent with Walker et al. (2018) and Ssemugenyi, (2023).

Teamwork benefited from the approach, with 85.7% agreeing their ability to work in teams improved, 8.2% neutral, and 6.1% disagreeing or strongly disagreeing. Overall satisfaction remained strong, with 79.5% agreeing, 12.3% neutral, and 8.1% disagreeing or strongly disagreeing.

The findings of the study suggest that problem-based learning significantly influences students' learning perception in electrical energy and electronics. The students demonstrated a generally positive disposition toward this instructional approach across various dimensions, including understanding of concepts, practical skill development, motivation, collaboration, confidence, and satisfaction.

The overwhelmingly positive responses from students on all ten questionnaire items confirm that problem-based learning (PBL) significantly improved their learning experiences and outcomes in the study of electrical energy and electronics. The findings support a broad consensus in educational literature that PBL enhances engagement, conceptual understanding, and science process skills.

Students reported a better understanding of electrical concepts through problem-solving, a result supported by Chistyakov et al., (2023), who noted that PBL helps make abstract science more relatable through real-world applications.

Improvements in practical skills such as circuit work were also widely noted, aligning with Kadir et al., (2023), who found that inquiry-based learning strengthens both theoretical and hands-on competence.

Students appreciated the opportunity to work in groups, echoing Vygotsky's social constructivist theory, which highlights the role of peer interaction in cognitive development

(Saleh et al., 2019). Students also expressed increased confidence in analysing and designing systems, reflecting findings by Severance et al. (2025) on how inquiry-based tasks foster self-efficacy.

Real-world contexts made lessons more meaningful, as Nguyen et al. (2021) and Osika et al. (2022) have similarly shown. Enhanced research skills were another gain, with students citing improved autonomy and data-handling abilities, confirming Jumhur et al.'s (2024) findings. Other outcomes included stronger connections between theory and practice which supports the work of Nicholus et al., (2023) higher motivation (Beagon et al., 2019), and improved teamwork skills (Roberts et al., 2022). The high levels of student satisfaction mirror earlier studies by Nicholus et al., (2023) which found that PBL environments lead to greater enthusiasm, retention, and academic achievement. Overall, the results affirm that PBL is a highly effective and well-received instructional strategy.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter provides the summary of the research findings, conclusions and the recommendations from the study. The discussions, conclusions and recommendations were made in accordance with the purpose of the study and research objectives. Finally, the areas for further research are suggested for consideration in future studies.

5.1 Summary of Findings

This study examined the effect of Problem-Based Learning (PBL) on their acquisition of Science Process Skills (SPS) students' and academic performance in Integrated Science, focusing on the topics of Electrical Energy and Electronics at the senior high school level. The study was motivated by the consistently low performance of students in Integrated Science South Dayi District. These challenges are largely attributed to the over-reliance on teacher-centred lecture methods, which limit opportunities for active learning and scientific inquiry. Grounded in the theory of social constructivism (Vygotsky, 1978), the research emphasised that learning is enhanced when students actively construct knowledge through interaction, collaboration, and problem solving.

The study employed a quasi-experimental pre-test and post-test research design for both the experimental and control groups. Two intact second-year classes from Peki Senior High School and Peki Senior High Technical School in the Volta Region of Ghana were purposively sampled. The experimental group was taught using PBL, whereas the control group was taught using traditional methods of lectures. Data collection instruments were weekly SPS assessment assignments, achievement tests, and a perception survey. Despite experiencing some difficulties, e.g., larger than ideal-sized classes, PBL was implemented successfully, and the relatively even gender split of the sample allowed for valid comparison between male and female students.

The results showed that PBL had a clear positive impact on SPS learning by the students. Scores in weekly tests showed consistent improvement in the five process skills of observing, measuring, inferring, predicting, and classifying. Taking observation, for instance, it improved from a mean of 2.30 in Week 1 to 2.91 in Week 5, while measurement improved from 2.40 to 2.98. Similarly, the mean score for inferring skills improved from 2.10 to 2.74, while mean score on predicting skills increased from 2.20 to 2.80, and mean score on classifying skills increased from 2.35 to 2.89. These steady gains demonstrate that PBL effectively build up students' skill to observe keenly, make accurate measurements, classify objects orderly, draw logical inferences, and make predictions all of which are basic skills to scientific inquiry and problem-solving. Academic performance also registered a remarkable improvement under the PBL scheme.

The mean score of the experimental group increased from 2.57 in the pre-test to 11.35 in the post-test, whereas that of the control group increased from 2.52 to 8.13. The post-test means difference of 3.22 was significant ($t = 6.38$, $p = 0.00$), which indicated that students taught using PBL outperformed those taught using the lecture method. The findings therefore indicate that PBL promotes better comprehension of scientific concepts and creates better problem-solving ability than conventional methodology. Further analysis showed that gender had no effect on performance. On average, male students performed 10.08 while female students performed 9.59, a non-significant difference of 0.49 ($p = 0.43$).

This finding shows that PBL is equally effective for male and female students and as a consequence, it is an inclusive pedagogy.

Students' attitudes towards PBL were very positive. The majority responded that the method improved their learning of scientific principles, research skills, motivation, and confidence. For example, 44.9% agreed and 38.8% strongly agreed that PBL improved their comprehension of electrical principles, while 91.9% attested that it improved their research skills. The majority of the students also indicated that PBL promoted collaboration, active learning and critical thinking and made lessons more interactive and relevant to real life. These perceptions corroborate the fact that PBL is not only academically effective but also inspiring and student-centred.

5.2 Conclusions

Based on the findings of this study, the researcher draws the following conclusions to each of the research questions;

The study revealed that students in the experimental group significantly outperformed those in the control group in their acquisition of science process skills. PBL provided opportunities for learners to engage in observing, predicting, measuring, and inferring, which improved their ability to apply theory to practice. The results showed that the use of PBL enhanced the development of science process skills more effectively than the lecture method.

The findings indicated that students taught with PBL achieved higher academic performance compared to those taught with the lecture method. Both groups showed improvement from pre-test to post-test, but the experimental group demonstrated greater gains in understanding and applying concepts in electrical energy and electronics. This confirmed that PBL strengthened students' academic achievement.

The analysis showed no statistically significant gender differences in the performance of male and female students within the experimental group. Both genders benefitted equally from the PBL approach. This suggests that PBL is a gender-responsive instructional method that provides balanced opportunities for all learners.

The interviews and questionnaire showed that students generally had positive perceptions of PBL. Although some initially found it challenging, most appreciated the approach for making lessons more engaging, collaborative, and relevant to real life. Students highlighted that PBL increased their motivation, improved teamwork, and enhanced their ability to connect classroom knowledge with practical applications.

5.3 Recommendations

Based on the findings the researcher makes the following recommendation;

1. Integrated Science teachers at Peki Senior High School should adopt a Problem-based Learning approach as it encourages students to actively engage in experiments and investigations, thereby enhancing their science process skills and practical understanding of scientific concepts.
2. Integrated Science teachers at Peki Senior High School should implement Problem-based Learning to improve students' academic performance, as this method promotes critical thinking, problem solving, and application of knowledge.

3. Problem-based Learning should be used in the teaching of Integrated Science to help bridge the gender gap in academic performance, providing all students, regardless of gender, equal opportunities to participate in hands on activities and collaborative problem solving.
4. Problem-based Learning should be employed to foster positive student perceptions of Integrated Science, as it makes lessons more interactive, relevant, and connected to real life situations, which can increase motivation and interest in the subject.

5.4 Suggested Areas for Further Research

To build on the findings of this study, the following areas are recommended for future research:

1. A longitudinal study on the sustained impact of PBL on students' academic performance and science process skills over multiple academic years.
2. Investigating the effect of PBL on students' creativity, problem-solving ability, and critical thinking in other Integrated Science topics beyond electrical energy and electronics.
3. Examining science teachers' attitudes, competencies, and challenges in implementing PBL at the SHS level.

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APPENDICES

APPENDIX A

Pre-Intervention Test on Academic Performance

Answer all questions. (20 marks)
DURATION: 30 minutes

Instructions: Answer all questions. Circle the correct option (A, B, C, or D) for each question and provide justification for your answer. In the spaces below

1. Which of the following laws states that the voltage across a conductor is directly proportional to the current through it, provided temperature remains constant?
A. Kirchhoff's Law
B. Coulomb's Law
C. Ohm's Law
D. Faraday's Law

…………………………………………………………………………………………………

2. The device used to measure electrical current in a circuit is called a/an:
A. Ammeter
B. Voltmeter
C. Galvanometer
D. Rheostat

…………………………………………………………………………………………………

3. A semiconductor material commonly used in electronic circuits is:
A. Copper
B. Aluminium
C. Iron
D. Silicon

…………………………………………………………………………………………………

4. The function of a fuse in an electrical circuit is to:
A. Increase voltage
B. Protect the circuit from excess current
C. Store electrical charge
D. Convert AC to DC

…………………………………………………………………………………………………

5. If a 240 V mains supply is connected to a 60 W lamp, what is the current drawn by the lamp?
A. 0.25 A

B. 0.50 A
C. 1.00 A
D. 4.00 A

………………………………………………………………………………………

6. The unit of electrical energy used by the Electricity Company of Ghana (ECG) for billing customers is the:
A. Watt (W)
B. Joule (J)
C. Kilowatt-hour (kWh)
D. Ampere-hour (Ah)

………………………………………………………………………………………

7. A 240 V, 60 W electric bulb is switched on for 5 hours. The energy consumed is:
A. 0.3 kWh
B. 1.2 kWh
C. 12 kWh
D. 120 kWh

………………………………………………………………………………………

8. The total resistance in a series circuit with three resistors of 2Ω, 4Ω, and 6Ω is:
A. 12Ω
B. 10Ω
C. 6Ω
D. 3Ω

………………………………………………………………………………………

9. A light-dependent resistor (LDR) functions by:
A. Emitting light when current flows
B. Increasing resistance in bright light
C. Decreasing resistance in bright light
D. Converting heat energy into electrical energy

………………………………………………………………………………………

10. What type of electronic component is used to convert alternating current (AC) to direct current (DC)?
A. Transistor
B. Resistor
C. Diode
D. Transformer

……………………………………………………………………………………………

11. The main advantage of using LEDs over incandescent bulbs is that LEDs:
A. Consume less power
B. Have lower efficiency
C. Generate more heat
D. Have a shorter lifespan

……………………………………………………………………………………………

12. The type of diode that allows current to flow in one direction only is called a:
A. Zener diode
B. Light-emitting diode (LED)
C. Rectifier diode
D. Photodiode

……………………………………………………………………………………………

13. Which of the following quantities is a unit of measure of electrical energy?
A. kWh
B. ohms
C. watts
D. ampere

……………………………………………………………………………………………

14. A relay is used in electrical circuits mainly to:
A. Store electric charge
B. Reduce power loss
C. Switch circuits using an electromagnetic coil
D. Convert AC to DC

……………………………………………………………………………………………

15. If two 100Ω resistors are connected in parallel, the equivalent resistance is:
A. 200Ω
B. 150Ω
C. 50Ω
D. 25Ω

……………………………………………………………………………………………

16. The total resistance in a series circuit with three resistors of 2Ω, 4Ω, and 6Ω is:
A. 12Ω
B. 10Ω

C. 6Ω
D. 3Ω

……………………………………………………………………………………………

17. In a PN junction diode, the depletion region is formed due to:
A. The flow of free electrons
B. The recombination of electrons and holes
C. The increase in resistance
D. The application of forward bias

……………………………………………………………………………………………

18. A transformer works based on the principle of:
A. Ohm's Law
B. Electromagnetic induction
C. Electrolysis
D. Photoelectric effect

……………………………………………………………………………………………

19. In an electronic circuit, a rectifier diode is primarily used to:
A. Control current flow
B. Convert AC to DC
C. Store energy
D. Increase circuit resistance

……………………………………………………………………………………………

20. Which electrical component stores energy in an electric field?
A. Resistor
B. Capacitor
C. Inductor
D. Transformer

……………………………………………………………………………………………

APPENDIX B

Marking Scheme for Pre-Intervention Test on Academic Performance

Question No.	Answer	Justification
1	C	Ohm's Law: Voltage is directly proportional to current at constant temperature.
2	A	Ammeter: Device used to measure current in a circuit.
3	D	Silicon: A commonly used semiconductor material.
4	B	Protects the circuit from excess current. Fuse melts to break the circuit when current is too high.
5	A	0.25 A. I = P/V = 60/240 = 0.25 A.
6	C	Kilowatt-hour (kWh), Commercial unit of electrical energy.
7	A	Correct value = 0.30 kWh, Computed from P × t = 0.060 kW × 5 h.
8	A	12Ω, Series resistances add up: 2 + 4 + 6 = 12Ω.
9	C	Decreasing resistance in bright light. LDR resistance falls as light intensity increases.
10	C	Diode Converts AC to DC (rectification).
11	A	Consume less power. LEDs are more efficient and last longer.
12	C	Rectifier diode. Allows current to flow in only one direction.
13	A	Correct unit is Joule or kWh
14	C	Switch circuits using an electromagnetic coil — Relay function.
15	C	50Ω. Two 100Ω resistors in parallel give 50Ω.
16	A	12Ω. Same as Q8, series resistances add directly.
17	B	The recombination of electrons and holes. Creates the depletion region.
18	B	Electromagnetic induction Transformer principle.
19	B	Convert AC to DC. Function of a rectifier diode.
20	B	Capacitor:Stores energy in an electric field.

APPENDIX C

Post -Intervention Test on Academic Performance

Answer all questions

Duration: 30 minutes

(20 marks)

Instructions: Circle the correct answer in the options provided and provide justification for your answer in each case in the spaces below.

1. Which electrical law helps analyze current in a complex circuit with multiple branches?
A. Ohm's Law
B. Faraday's Law
C. Kirchhoff's Current Law
D. Coulomb's Law

……………………………………………………………………………………………

2. What is the SI unit of electric power?
A. Volt
B. Ampere
C. Watt
D. Ohm

……………………………………………………………………………………………

3. A 120 V device draws 2 A of current. What is the power consumed?
A. 60 W
B. 240 W
C. 120 W
D. 2400 W

……………………………………………………………………………………………

4. In a series circuit, the total resistance is the:
A. Average of all resistances
B. Product of all resistances
C. Sum of all resistances
D. Difference between the largest and smallest resistors

……………………………………………………………………………………………

5. A component that stores electrical energy in an electric field is a:
A. Diode
B. Transistor

C. Capacitor
D. Resistor

…………………………………………………………………………………………

6. If three 10Ω resistors are connected in parallel, what is the equivalent resistance?
A. 3.33Ω
B. 30Ω
C. 10Ω
D. 1.11Ω

…………………………………………………………………………………………

7. A multimeter cannot measure:
A. Voltage
B. Resistance
C. Frequency
D. Current

…………………………………………………………………………………………

8. The transistor is used in a circuit to:
A. Act as a fuse
B. Switch or amplify signals
C. Measure voltage
D. Store charge

…………………………………………………………………………………………

9. The main purpose of a diode in a solar panel system is to:
A. Control voltage
B. Convert AC to DC
C. Prevent backflow of current
D. Store energy

…………………………………………………………………………………………

10. Which component opposes changes in current in AC circuits?
A. Resistor
B. Capacitor
C. Inductor
D. Diode

…………………………………………………………………………………………

11. The instrument that measures potential difference is:
A. Ammeter
B. Voltmeter
C. Rheostat
D. Galvanometer

…………………………………………………………………………………………

12. Electrical energy consumption in homes is billed in:
    A. kWh
    B. Ampere
    C. Joule
    D. Watt

    ………………………………………………………………………………………………

13. A 100 W fan operates for 10 hours. Energy consumed is:
    A. 1.0 kWh
    B. 10.0 kWh
    C. 1000 kWh
    D. 0.1 kWh

    ………………………………………………………………………………………………

14. AC is preferred for power distribution because it:
    A. Is more stable
    B. Can be stepped up or down easily
    C. Is more expensive
    D. Is safer

    ………………………………………………………………………………………………

15. The ability of a material to allow current to flow freely is called:
    A. Resistance
    B. Conductivity
    C. Capacitance
    D. Power

    ………………………………………………………………………………………………

16. A Zener diode is typically used to:
    A. Block current
    B. Store voltage
    C. Regulate voltage
    D. Generate heat

    ………………………………………………………………………………………………

17. In a DC circuit, current flows:
    A. In both directions
    B. From negative to positive terminal
    C. From positive to negative terminal
    D. Alternately

    ………………………………………………………………………………………………

18. Which circuit would remain functional if one component fails?
    A. Series
    B. Short
    C. Parallel
    D. Open

    ………………………………………………………………………………………………

19. Semiconductors conduct electricity:
    A. Only at absolute zero
    B. Only at very high temperatures
    C. Depending on conditions
    D. Better than metals

    ………………………………………………………………………………………………

20. What is the purpose of Kirchhoff's Voltage Law?
    A. Ensure equal current in each loop
    B. Sum of voltages around a loop is zero
    C. Maximum power delivery
    D. Induce EMF

    ………………………………………………………………………………………………

APPENDIX D

Marking Scheme for Post-Test on Academic Performance

		Justification
1	C	Kirchhoff's Current Law is used for analyzing current in branching circuits.
2	C	The SI unit of power is the watt (W).
3	B	Power = Voltage × Current = 120 × 2 = 240 W.
4	C	Total resistance in series is the sum of all resistors.
5	C	Capacitors store energy in electric fields.
6	A	$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} = \frac{1}{10} + \frac{1}{10} + \frac{1}{10}$, R =3.33Ω.
7	C	Most multimeters don't measure frequency directly.
8	B	Transistors are used to switch or amplify signals.
9	C	Diodes prevent backflow of current in solar circuits.
10	C	Inductors oppose changes in current in AC.
11	B	Voltmeters are used to measure potential difference.
12	A	ECG uses kilowatt-hours (kWh) for billing.
13	B	Energy = Power × Time = 100 W × 10 h = 1000 Wh = 1.0 kWh.
14	B	AC can be stepped up/down via transformers, making it better for transmission.
15	B	Conductivity is the ability to allow current flow.
16	C	Zener diodes are used to regulate voltage.
17	C	In DC, current flows from positive to negative terminal.
18	C	In a parallel circuit, other paths allow continued operation if one component fails.
19	C	Semiconductors conduct based on conditions (e.g., temperature, doping).
20	B	The total voltage around a loop is zero (law of conservation of energy).

APPENDIX E

Pre-Intervention test on science process skills

Answer all questions. 20 marks

Duration: 30 minutes

1. You are tasked to measure the current flowing through a bulb in a classroom circuit. Describe exactly how you would connect an ammeter to get an accurate reading.
   Answer:………………………………………………………………………………
   ……………………………...……………………………………………………………
   (1 mark)
   Provide reason for your answer:
   …………………………………………………………………………………………
   ……………………...…………………………………………………………(1 mark)
2. During a practical session, you are asked to measure the resistance of a heating coil using a digital multimeter. Why must you ensure the circuit is powered off before taking this measurement?
   Answer:………………………………………………………………………………
   ……………………………...…………………………………………………(1 mark)
   Provide reason for your answer:
   …………………………………………………………………………………………
   ……………………...…………………………………………………………(1 mark)

3. While repairing a classroom fan, what safety steps must you take before testing a high-voltage circuit? Mention at least two.
   Answer:………………………………………………………………………………
   ……………………………...…………………………………………………(1 mark)
   Provide reason for your answer:
   …………………………………………………………………………………………
   ……………………...…………………………………………………...…(1 mark)

4. You connect a capacitor to a battery and an LED in a classroom experiment. Describe what you observe and what it tells you about the capacitor's behavior.
   Answer………………………………………………………………………………
   ……………………………...……………………………………………… (1 mark)
   Provide reason for your answer:
   …………………………………………………………………………………………
   ……………………...……………………………………………………...……(1 mark)
5. Imagine you're testing how much current flows through a fuse in a fuse box. What must you do to ensure accurate current measurement, and what mistake must you avoid when

connecting the ammeter?
Answer:………………………………………………………………………………………
…………………………...…………………………………………………………………
……………………………………………………………………………………………
…
Provide reason for your answer:
……………………………………………………………………………………………
…………………...…………………………………………………..……(1 mark)

6. During a practical test, a 24V battery is connected to a circuit with a total resistance of 8Ω. Calculate the expected current, and describe how you would verify this in the lab.
Answer:………………………………………………………………………………………
…………………………...……………………………………………………(1 mark)
Provide reason for your answer:
……………………………………………………………………………………………
…………………...…………………………………………………..……(1 mark)

7. While observing a waveform on an oscilloscope in the lab, you see a sinusoidal pattern. What kind of current is flowing in the circuit, and what does the waveform tell you about its nature?
Answer:………………………………………………………………………………………
…………………………...……………………………………………………(1 mark)
Provide reason for your answer:
……………………………………………………………………………………………
…………………...…………………………………………..……………………(1 mark)

8. A 1.2 kΩ resistor is measured to be 1.15 kΩ in a school lab using a multimeter. Is this reading acceptable? Why or why not?
Answer:………………………………………………………………………………………
………………………...……………………………………………………………(1 mark)
Provide reason for your answer:
……………………………………………………………………………………………
…………………...…………………………………………………………………(1 mark)

9. In a lab investigation, you replaced a wire with a longer one of the same material and thickness and noticed increased resistance. What principle is demonstrated, and how is it practically useful in wiring installations?
Answer:………………………………………………………………………………………
…………………………...……………………………………………………(1 mark)

Provide reason for your answer:
……………………………………………………………………………………………
…...…………………………………………………………………………………………

10. In an experiment with a diode and a battery, the LED only lights up in one connection direction. Explain why this happens and how this property is used in phone chargers. Answer:……………………………………………………………………………………
………………………………..………………………………………………(1 mark)
Provide reason for your answer:
………………………………………………………………………………………………
……………………..…………………………………………………………(1 mark)

APPENDIX F

Marking scheme for pre-intervention test on science process skills

1mark each for a correct answer and a correct justification

Answer: Connect the ammeter in series with the bulb. **Justification:** This ensures all current flowing to the bulb also flows through the ammeter, allowing accurate measurement.

Answer: The circuit must be powered off before measuring resistance. **Justification:** A live circuit can cause inaccurate readings and may damage the multimeter due to the presence of external current.

Answer: (1) Switch off the power supply. (2) Use insulated tools and gloves. **Justification:** Turning off power prevents shocks, and insulated tools protect against accidental contact with live components.

Answer: The LED lights briefly and then dims.
Justification: This indicates the capacitor is charging; current flows initially and stops once the capacitor is full.

Answer: Connect the ammeter in series with the fuse. Avoid connecting it in parallel. **Justification:** Series connection allows all current to pass through the ammeter; parallel connection could short the circuit due to low resistance.

Answer: Current = 3 Amps ($I = V/R = 24V/8\Omega$).
Justification: Connect an ammeter in series to measure and verify the calculated current.

Answer: Alternating Current (AC) is flowing.
Justification: The sinusoidal waveform shows voltage and current reversing direction periodically, which is characteristic of AC.

Answer: Yes, it is acceptable.
Justification: The resistor's tolerance allows for slight variations; 1.15 kΩ is within a typical ±5% range of 1.2 kΩ.

Answer: Longer wires have higher resistance.
Justification: According to $R = \rho L/A$, increasing length increases resistance. Shorter wires are preferred to reduce power loss.

Answer: The diode only allows current in one direction.
Justification: This is called rectification; it's used in phone chargers to convert AC to DC safely.

APPENDIX G

Post-intervention test on science process skills

Answer all questions. 20 marks

Duration: 30 minutes

Study the circuit diagrams carefully and use it to answer questions 1 to 3.

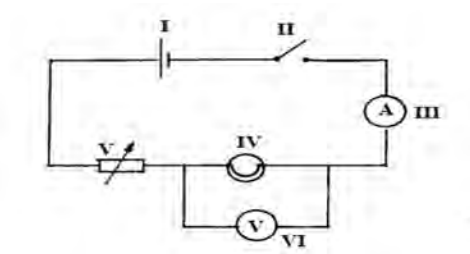

Fig.1

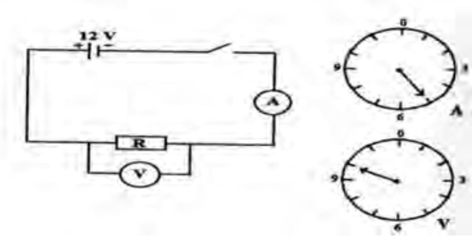

Fig. 2

1. From fig 2, read and record the ammeter and voltmeter readings (2 marks)
a). Ammeter reading: …………………………………………………………………
b). Voltmeter reading: ……………………………………………………………

2. Using the readings from fig 2, determine the resistance (R) of the resistor. Show your working.
(2 marks)

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

3. what would happen to the ammeter and voltmeter readings if the resistance R is decreased.
…………………………………………………………………………………………
……………………………………………………………………………… (1 marks)

Give reason for your answer
……………………………………………………………………………………(1 marks)

4. A student connects two bulbs in series to a battery. Compared to using one bulb, both bulbs now glow dimmer. Explain what this shows about the current in the circuit.

Answer:…………………………………………………………………………………
………………………………...……………………………………………………………

Provide reason for your answer ………………………………………………………...

………………………………………………………………………………………(1 marks)

5. After switching on a parallel circuit, a student notices both bulbs glow equally bright. What can you say about the voltage across each bulb, and why?

Answer………………………………………………………………………………
……………………...………………………………………………………………. (1 marks)

Provide reason for your answer ………………………………………………………...
……………………………………………………………………………………….. (1 marks)

6. During a classroom demonstration, a student sees an LED light up only when connected in one direction. What does this reveal about how an LED works?

Answer………………………………………………………………………………
……………………...……………………………………………………. ………. (1 marks)

Provide reason for your answer ………………………………………………………...
……………………………………………………………………………………… (1 marks)

6.In a circuit, one resistor follows another in a single path. Describe how this circuit should be classified and why.

Answer………………………………………………………………………………
………………………………...……………………………………………………… (1 marks)

Provide reason for your answer………………………………………………………...
……………...……………...……………………………………………………….. (1 marks)

Study fig 3 bellow carefully and answer the questions that follow

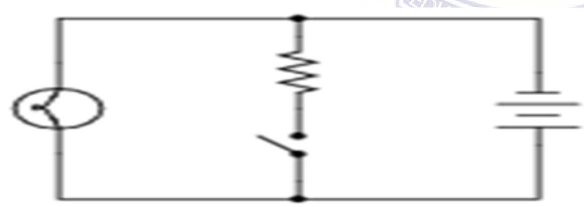

Fig 3

7.What will happen to the brightness of the light bulb if the number of cells is increased in the circuit in fig 3?

.... (1 mark)

Give reason for your answer ………………………………………………………...
……………………………………………………………………… (1 mark)

8.Explain why the voltmeter is connected in parallel and the ammeter in series in the circuit.
Answer………………………………………………………………………………
………………………………...……………………………………………………. (1 mark)

Provide reason for your answer ………………………………………………………………
………....……………………………………………………………………………(1 mark)

9.What inference can be made about the relationship between current and voltage in this experiment?
Answer:…………………………………………………………………………..………

……………………………………………...…………………………… … (1 mark)

Provide reason for your answer ………………………………………………………………
……………………………………………………………………………...(1 mark)

APPENDIX H

Marking Scheme for Post-Test on Science Process Skills

Total marks = 20

1. Ammeter reading: (5 A) 1 mark

   Voltmeter reading: 10V) 1 mark

2. Calculating Resistance

Use of Ohm's Law: V=IR (1 mark)

R= $\frac{V}{I}$ R= $\frac{10}{2}$ = 2 Ω (1 mark)

3. Expected change (1 mark):

Ammeter reading increases,

Voltmeter reading decreases slightly or remains the same depending on configuration.

Reason: Lower resistance allows more current to flow (Ohm's Law: I increases as R decreases).

(1 mark)

4. Answer: Current increases as voltage increases, or they are directly proportional. (1 mark):

Reason: Ohm's Law: I=VR. at constant resistance, current increases with voltage.

(1 mark):

5. Answer: The current is reduced when more resistive components (bulbs) are added in series. (1 mark):

Reason: More resistance in series decreases current, causing both bulbs to be dimmer. (1 mark)

6. Answer The voltage across each bulb is the same. (1 mark):

Reason: In a parallel circuit, all branches receive the full supply voltage. (1 mark):

7. Answer: LEDs only allow current to flow in one direction. (1 mark):

Reason: LEDs are diodes; they conduct when forward-biased and block when reversed. (1 mark):

8. Answer: It is a series circuit. (1 mark):

Reason: All current flows through a single path with each resistor placed one after the other. (1 mark)

9. Answer: Brightness of the bulb increases. (1 mark):

Reason: More cells increase total voltage, increasing current and power to the bulb (P=IV).

(1 mark):

10. Answer: Voltmeter is connected in parallel; ammeter in series. (1 mark):

Reason: Voltmeter must measure potential difference across a component, and ammeter must measure total current through the circuit. (1 mark)

APPENDIX I

Questionnaire for students' perception on Problem-Based Learning

Please indicate your level of agreement with each of the following statements regarding your experience with lessons involve solving problems in learning electrical energy and electronics. Tick [✓] the appropriate box for each statement as applied to you using Strongly Disagree (SD), Disagree (D), Neutral(U), Agree (A) Strongly Agree (SA)

S/N		SD	D	U	A	SA
1.	Solving problems during lesson has enhanced my understanding of electrical energy and electronics concepts.					
2.	Engaging in lessons involve solving problems has improved my practical skills in electrical circuits and electronic devices.					
3.	Working with peers during lessons in solving problems has enhanced my abilities to solve simple problem in electrical engineering scenarios.					
4.	The lesson has increased my confidence in designing and analyzing simple electrical and electronic systems.					
5.	The real-world problems addressed in the lessons have made learning electrical energy and electronics more engaging.					
6.	Through the lessons, I have developed better research skills especially in electrical energy and electronics topics.					
7.	The lessons have helped me connect theoretical knowledge of electrical energy and electronics to practical applications.					
8.	I am more motivated to learn about electrical energy and electronics through solving problems compared to the old teaching methods that our teacher use.					
9.	Solving problems during the lessons have improved my ability to work effectively in group					
10	Overall, I am satisfied with my learning experience in electrical energy and electronics through solving problem.					

APPENDIX J

Interview Guide: Assessing Students' Perceptions of Solving Problems in Electrical Energy and Electronics lessons.

1. How would you describe your initial reaction to the approach of solving problems when it was first introduced in your electrical energy and electronics lessons six weeks ago?

   ……………………………………………………………………………………………

2. Can you share specific examples of problem-solving activities or projects you participated in during these lessons?

   ……………………………………………………………………………………………

3. In what ways do you think solving problems has influenced your understanding of electrical energy and electronics concepts?

   ……………………………………………………………………………………………

4. Do you feel that engaging in problem-solving activities has enhanced your practical skills in electrical circuits and electronic devices? Please give reasons.

   ……………………………………………………………………………………………

5. How has collaborating with peers during problem-solving sessions affected your ability to solve real-life electrical engineering challenges?

   ……………………………………………………………………………………………

6. Can you discuss any improvements in your communication skills as a result of participating in problem-solving activities?

   ……………………………………………………………………………………………

7. Can you provide an example of how solving problems has helped you apply theoretical knowledge to practical situations in electrical energy and electronics?
   ………………………………………………………………………………………………

8. How has the problem-solving approach affected your motivation to learn about electrical energy and electronics compared to traditional teaching methods?
   ………………………………………………………………………………………………

9. Have you found the real-world problems addressed through this approach to be engaging and relevant? Please explain.
   ………………………………………………………………………………………………

10. What challenges, if any, have you encountered while engaging in problem-solving activities?
    ………………………………………………………………………………………………

11. Do you have suggestions for improving the use of problem-solving in electrical energy and electronics lessons?
    ………………………………………………………………………………………………

12. Overall, how satisfied are you with your learning experience in electrical energy and electronics through solving problems?
    ………………………………………………………………………………………………

13. Would you recommend that science teachers adopt the problem-solving approach in the teaching and learning of Integrated Science? Why or why not?
    ………………………………………………………………………………………………

APPENDIX K

Observation Guide for Assessing Science Process Skills

Student's Index ……………………………………....

Process Skills	Score	Performance Indicators
Observing	0	No purposeful observation recorded.
	1	Observations are vague; records few details; needs prompting.
	2	Identifies some circuit behaviors but misses important details (e.g., bulb flickering, wrong polarity).
	3	Notices and records most circuit behaviors; observations are generally accurate.
	4	Accurately observes and records circuit behavior (bulbs dim/bright, current direction, sparks, heat in resistors, etc.); uses appropriate instruments (ammeter, voltmeter) without error.
Measuring	0	Does not attempt to measure.
	1	Needs prompting to select/use instrument; inaccurate readings.
	2	Uses instrument but with frequent errors; records incomplete data.
	3	Measures correctly with minor errors in scale reading or units.
	4	Selects correct instrument (voltmeter/ammeter/multimeter), uses proper scale, records voltage/current/resistance with correct units & precision.
Inferring	0	No inference given.
	1	Incorrect inference; little/no justification.
	2	Inferences partly supported but mixed with guesses.
	3	Inferences mostly supported by data but with minor gaps.

	4	Draws logical conclusions about relationships (e.g., current decreases when resistance increases) using collected data; justifies inferences with evidence.
Predicting	0	No prediction given.
	1	Random guesses; no reasoning.
	2	Predictions partly plausible; weak link to theory/data.
	3	Predictions consistent with theory but explanation weak.
	4	Makes accurate, testable predictions (e.g., If another bulb is added in series, brightness will decrease) and justifies using Ohm's Law or circuit rules.
Classifying	0	No attempt to classify.
	1	Random grouping; needs prompting.
	2	Some correct, some misclassified; rule unclear.
	3	Classifications mostly correct; rule stated but partially applied.
	4	Correctly classifies components (series vs parallel, conductor vs insulator, high vs low resistance) and justifies rule clearly.

Recording Sheet (one per learner)

Skill	0	1	2	3	4	Notes
Observing	☐	☐	☐	☐	☐	
Measuring	☐	☐	☐	☐	☐	
Inferring	☐	☐	☐	☐	☐	
Predicting	☐	☐	☐	☐	☐	
Classifying	☐	☐	☐	☐	☐	

Total score = 20

Rating Scale

0 = Not evident (skill not demonstrated at all)

1 = Emerging (rarely demonstrates skill; relies on prompting)

2 = Developing (sometimes demonstrates skill; needs guidance)

3 = Proficient (often demonstrates skill correctly with minor errors)

4 = Excellent (always demonstrates skill independently & accurately)

APPENDIX L: Problem-Based Learning Method Lesson Plans for the Experimental Group

WEEK ONE

General Objective

By the end of the lesson, learners should be able to define voltage, current, resistance, and power, explain their interrelationships, identify circuit components, and use Ohm’s Law to analyze simple circuits.

Prior Knowledge (RPK)

Learners have knowledge of basic electrical components such as bulbs, batteries, and switches from Junior High School.

Week Ending:11th April, 2025	Subject: Integrated Science	Time: 9:30-11:20am
Date: 8th April, 2025	Topic Electricity	Duration: 100 minutes
Class: SHS 2	Sub-Topic: Voltage, Current, Resistance, and Power	Class Size: 49
References	Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide; Ministry of Education (2010). Teaching Syllabus for Integrated Science; Oddoye, E. O. et al. (2011). Integrated Science for SHS	

Step	**Teacher Activities**	**Learner Activities**	**Resources**
1. Identify/Present the Problem (5 min)	Present scenario: 'Your school experiences frequent voltage fluctuations causing damage to electrical appliances. Investigate the problem and propose	Listen attentively, ask questions, and understand the context.	Whiteboard, markers

	solutions.' Write problem on board.		
2. Clarify the Problem & Key Terms (5 min)	Guide discussion on meaning of voltage fluctuations. Define voltage, current, resistance, power, and Ohm's Law.	Discuss in groups and share experiences of power fluctuations at home or school.	Textbooks, charts
3. List What is Already Known (5 min)	Ask probing questions about electrical circuits and safety.	Brainstorm in groups what they know about voltage, current, resistance, and power.	Worksheets
4. Identify What Needs to be Learned (Learning Issues) (5 min)	Help learners identify knowledge gaps (e.g., causes of fluctuations, safety devices).	List questions such as 'What causes fluctuations?' and 'How can circuits be stabilized?'	Worksheets
5. Assign Learning Tasks (Self-Directed Learning) (50 min)	Form groups, assign roles, and provide materials.	Research, design and test simple circuits using Ohm's Law to calculate values.	Batteries, bulbs, resistors, wires, multimeters
6. Share Findings & Discuss (10 min)	Move around groups, ask questions, correct misconceptions.	Present group findings, relate results to real-life voltage problems.	Group reports
7. Generate Possible Solutions (10 min)	Encourage application of concepts to suggest solutions.	Brainstorm strategies (voltage regulators, surge protectors, rewiring).	Flipchart, markers
8. Present & Defend Solutions (5 min)	Facilitate group presentations and Q&A.	Present proposed solutions and defend them with scientific reasoning.	Presentation tools
9. Reflect & Evaluate (5 min)	Summarize key points, correct misconceptions, link to real-world electrical safety.	Reflect on learning outcomes, give peer feedback.	Reflection sheets

Core Points	**Evaluation**	**Remarks**
- Voltage (V): Potential difference - Current (I): Flow of charge - Resistance (R): Opposition to flow - Power (P): Rate of energy use - Ohm's Law: V=IR	1. Define voltage, current, resistance, and power. 2. State Ohm's Law. 3. Draw and label a simple circuit. 4. Calculate current in a circuit with 24V and 8Ω resistance, and explain what happens if resistance doubles.	……………………………………

WEEK TWO

Objectives

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

1. Explain Ohm's Law and its application in circuit.
2. State and apply Kirchhoff's Current and Voltage Laws.
3. Solve circuit problems using Kirchhoff's and Ohm's Laws.

RPK

Students have already learnt about voltage, current, resistance, and power in their previous lesson.

Week Ending: 18th April, 2025	Subject: Integrated Science	Time: 9:30-11:20am
Date: 15th April, 2025	Topic Electricity	Duration: 100 minutes
Class: SHS 2	Sub-Topic: Circuit Analysis Using Ohm's and Kirchhoff's Laws	Class Size: 49
References	Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide; Ministry of Education (2010). Teaching Syllabus for Integrated Science; Oddoye, E. O. et al. (2011). Integrated Science for SHS	

Step	Teacher Activities	Learner Activities	Resources
1. Identify/Present the Problem (5 min)	Presents scenario: 'A local electrician is struggling to design an efficient wiring system for a new classroom block. Investigate how Ohm's and Kirchhoff's Laws can help optimize the circuit design.' Writes it on the board.	Listen attentively, ask clarifying questions, and brainstorm the meaning of 'efficient wiring.'	Whiteboard, markers
2. Clarify the Problem & Key Terms (5 min)	Guides discussion on Ohm's Law, Kirchhoff's Current Law (KCL), and Kirchhoff's Voltage Law (KVL). Provides simple examples.	In groups, discuss meanings, connect to daily electrical experiences, and share prior knowledge.	Textbooks, charts
3. List What is Already Known (5 min)	Asks probing questions about electrical circuits, loops, and current distribution.	Brainstorm in groups, recall prior knowledge, and write down what is already known.	Worksheets
4. Identify What Needs to be Learned (5 min)	Helps learners frame questions on gaps: 'How do we apply KCL at a junction?' 'How do we use KVL in loops?'	List specific questions to guide their investigation.	Worksheets
5. Assign Learning Tasks (Self-Directed Learning) (50 min)	Demonstrates a simple circuit. Divides class into groups, distributes materials, and assigns exploration: build circuits, take measurements, apply Ohm's Law, KCL, and KVL.	In groups, assign roles, build/test circuits, measure voltage/current, apply formulas, solve equations, record findings.	Batteries, resistors, wires, multimeters
6. Share Findings & Discuss (10 min)	Moves between groups, asks questions, addresses misconceptions, facilitates discussion.	Present group findings and explain how they relate to the electrician's wiring problem.	Group reports

7. Generate Possible Solutions (10 min)	Encourages groups to propose wiring strategies using Ohm's and Kirchhoff's Laws.	Brainstorm optimized solutions and prepare short reports.	Flipchart, markers
8. Present & Defend Solutions (5 min)	Facilitates group presentations and moderates Q&A.	Present solutions, defend reasoning using scientific principles, respond to feedback.	Presentation tools
9. Reflect & Evaluate (5 min)	Summarizes key points, corrects misconceptions, and connects lesson to real-world applications.	Reflect on learning, provide peer feedback, and self-evaluate.	Reflection sheets

Core Points	**Evaluation**	**Remarks**
Ohm's Law: $V = IR$. If two values are known, the third can be calculated. Kirchhoff's Current Law (KCL): The total current entering a junction equals the total current leaving ($\sum I_{in} = \sum I_{out}$). Application: Useful for analyzing parallel circuits. Kirchhoff's Voltage Law (KVL): The algebraic sum of voltages around a closed loop is zero ($\sum V = 0$). Application: Useful for solving unknown voltages or resistances in loops.	Explain Ohm's Law and give one example of its application. State Kirchhoff's Current Law and Kirchhoff's Voltage Law. A 12 V battery is connected in series with two resistors:	…………………………………

WEEK THREE

General Objectives

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

1. Explain the differences between series and parallel circuits.
2. Calculate total resistance, voltage, and current in both circuit types.
3. Identify practical applications of series and parallel circuits.

RPK

Students have already learnt about voltage, current, resistance, and power in their previous lesson.

Week Ending: 25th April, 2025	Subject: Integrated Science	Time: 9:30-11:20am
Date: 22nd April, 2025	Topic Electricity	Duration: 100 minutes
Class: SHS 2	Sub-Topic: Series and Parallel Circuit Calculations	Class Size: 49
References	Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company. Ministry of Education (2010). Teaching Syllabus for Integrated Science; Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra. Oddoye, E. O. et al. (2011). Integrated Science Senior High Schools, Student's Book. Accra: Sam Woode Ltd.	

Step	Teacher Activities	Learner Activities	Resources
1. Identify/Present the Problem (5 min)	Presents scenario: 'Your school wants to install a lighting system for a new computer lab. Investigate whether a series or parallel circuit is more suitable for this purpose and justify your choice.' Writes the problem on the board.	Listen attentively, ask clarifying questions, brainstorm ideas about lighting systems.	Whiteboard, markers
2. Clarify the Problem & Key Terms (5 min)	Guides discussion on series and parallel connections. Defines key concepts (current, voltage, resistance in each type).	In groups, discuss meanings, share prior experiences, and connect to the problem.	Textbooks, charts
3. List What is Already Known (5 min)	Asks probing questions to recall what students know about current, voltage, and resistance in circuits.	Brainstorm in groups and write down prior knowledge.	Worksheets
4. Identify What Needs to be Learned (5 min)	Helps learners identify gaps: e.g., 'What happens when a bulb is removed?' 'How do we calculate total resistance in series and parallel?'	List specific questions to guide investigations.	Worksheets
5. Assign Learning Tasks (Self-Directed Learning) (50 min)	Provides materials. Guides groups to build both series and parallel circuits, measure values, and apply formulas.	Build simple series and parallel circuits. Measure voltage, current, and resistance. Observe effects	Batteries, resistors, wires, bulbs, multimeters

	Moves around to support learning.	when one bulb is removed. Record results for comparison.	
6. Share Findings & Discuss (10 min)	Moves around groups, asks questions, corrects misconceptions.	Present findings and compare series vs. parallel circuits.	Group reports
7. Generate Possible Solutions (10 min)	Encourages groups to decide which connection is best for the computer lab and justify.	Brainstorm solutions and prepare short written recommendations.	Flipchart, markers
8. Present & Defend Solutions (5 min)	Facilitates presentations and Q&A.	Present solutions, defend choice using scientific reasoning.	Presentation tools
9. Reflect & Evaluate (5 min)	Summarizes main differences, highlights applications, links to real-world use of circuits.	Reflect on what was learned, provide peer feedback, self-evaluate.	Reflection sheets

Core Points	**Evaluation**	**Remarks**
Series Circuit: Components connected end-to-end; one path for current. Current is the same through all components. Voltage is shared. If one component fails, the circuit stops. Parallel Circuit: Components connected across common points; multiple paths for current. Voltage is the same across branches. Current divides. If one component fails, others still work. Applications: Series – torchlight, Christmas lights. Parallel – household wiring, car systems, classroom lights.	Explain two differences between series and parallel circuits. State two applications of each type of circuit. A 12 V battery is connected in series with two resistors: a) Calculate the total resistance. b) Find the total current.	…………………………………

WEEK FOUR

Objectives

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

1. Explain electrical energy consumption and its unit, kilowatt-hour (kWh).
2. Calculate power consumption and energy usage of common household appliances.
3. Use a multimeter to measure voltage and current in simple circuits.

RPK

Students have already learnt about electrical energy, power, and common electrical appliances.

Week Ending: 2nd May, 2025	Subject: Integrated Science	Time: 9:30-11:20am
Date: 29th April, 2025	Topic Electricity	Duration: 100 minutes
Class: SHS 2	Sub-Topic: Electrical Energy Consumption and Measuring Instruments	Class Size: 49
References	Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company. Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra. Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.	

Step	Teacher Activities	Learner Activities	Resources
1. Identify/Present the Problem (5 min)	Presents a household electricity bill and asks: 'Why are energy bills in our community rising?' Writes the problem on the board.	Listen attentively, ask clarifying questions, brainstorm causes of high energy consumption.	Whiteboard, markers, sample electricity bill
2. Clarify the Problem & Key Terms (5 min)	Guides discussion on electrical energy consumption, kilowatt-hour (kWh), power ratings, and tariffs.	Discuss in groups, share experiences from home about electricity usage.	ECG tariff chart, textbooks
3. List What is Already Known (5 min)	Asks probing questions on previous knowledge of power, energy, and appliances.	Brainstorm what they already know about energy use and measurement, record on worksheets.	Worksheets
4. Identify What Needs to be Learned (5 min)	Helps learners raise questions: 'How do we calculate energy in kWh?' 'Which appliances consume the most energy?' 'How do we measure voltage and current?'	Formulate sub-questions to guide investigation.	Worksheets
5. Assign Learning Tasks (Self-Directed Learning) (50 min)	Demonstrates safe use of a multimeter. Provides appliances, calculators, and worksheets. Guides groups to take measurements, record, and calculate energy.	In groups: Use multimeter to measure current and voltage. Calculate power and energy consumption of appliances. Estimate cost using tariff rate. Identify appliances with highest energy usage.	Multimeters, sample appliances, calculators, ECG tariff chart, worksheets
6. Share Findings & Discuss (10 min)	Moves between groups, asks questions, corrects misconceptions.	Present group calculations of energy use and costs.	Group reports
7. Generate Possible Solutions (10 min)	Encourages students to propose energy-saving measures at home and school.	Brainstorm strategies (e.g., switching off unused appliances, using energy-efficient bulbs).	Flipchart, markers

8. Present & Defend Solutions (5 min)	Facilitates group presentations and Q&A.	Present solutions, defend recommendations with data and reasoning.	Presentation tools
9. Reflect & Evaluate (5 min)	Summarizes energy consumption concepts, connects findings to national energy-saving campaigns.	Reflect on learning, peer-assess presentations, self-evaluate.	Reflection sheets

Core Points	**Evaluation**	**Remarks**
Electrical energy consumption refers to the amount of electrical energy used by an appliance or device over time. Formula: Energy (kWh) = Power (kW) × Time (h). Cost of electrical energy consumption: Cost = Energy consumed (in kWh) × Cost per unit (tariff). Example: A 1500 W (1.5 kW) heater is used for 4 hours/day for 10 days. Energy = 1.5 × 4 × 10 = 60 kWh. Cost = 60 × 1.20 = GHS 72.00. Measuring Instruments: Multimeters measure current (A), voltage (V), and resistance (Ω).	What is electrical energy consumption? A 2000 W (2 kW) heater is used for 30 minutes per day for 3 days. Calculate: a) The energy consumed. b) The cost if the tariff is GHS 1.20 per kWh. Demonstrate how to use a multimeter to measure voltage and current in a circuit.	…………………………………

WEEK FIVE

General Objectives

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

1. Identify and describe the functions of resistors, capacitors, diodes, and transistors.
2. Explain how diodes regulate current flow in one direction in a circuit.
3. Describe the role of transistors as switches and amplifiers in electronic circuits.

RPK

Students have already learnt about electrical energy consumption and measuring instruments.

Week Ending: 9th May, 2025	Subject: Integrated Science	Time: 9:30-11:20am
Date: 6th May, 2025	Topic Electricity	Duration: 100 minutes
Class: SHS 2	Sub-Topic: Electrical Energy Consumption and Measuring Instruments	Class Size: 49
References	Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company. Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra. Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.	

Step	Teacher Activities	Learner Activities	Resources
1. Identify/Present the Problem (5 min)	Presents scenario: 'Your school plans to set up a solar power system. Investigate how electronic components like resistors, capacitors, diodes, and transistors function in such a system.'	Listen attentively, ask clarifying questions, and brainstorm the role of components in solar systems.	Whiteboard, markers, solar system diagram
2. Clarify the Problem & Key Terms (5 min)	Introduces block diagram of a solar power system, points out where diodes and transistors are applied. Guides class discussion on the function of basic electronic components.	Work in groups to define terms and share knowledge about each component.	Charts, textbooks
3. List What is Already Known (5 min)	Asks probing questions about prior knowledge of resistors, capacitors, diodes, and transistors.	Recall uses of basic components (e.g., bulbs with resistors, capacitors in radios). Record ideas on worksheets.	Worksheets
4. Identify What Needs to be Learned (5 min)	Guides learners to ask questions such as: 'How do diodes allow current in one direction?' 'How do transistors act as switches and amplifiers?'	List investigative questions for exploration.	Worksheets
5. Assign Learning Tasks (Self-Directed Learning) (50 min)	Assigns each group one component to investigate. Provides simplified circuit diagrams and physical	Groups observe and test components, record findings (e.g., measure resistance, observe capacitor charge/discharge, test	Resistors, capacitors, diodes, transistors, simplified circuit setups

	components. Demonstrates safe handling.	diode directionality, test transistor as a switch/amplifier).	
6. Share Findings & Discuss (10 min)	Facilitates group reporting and clarifies misconceptions.	Groups present findings about their assigned components.	Group reports
7. Generate Possible Solutions (10 min)	Encourages groups to apply component functions to solving solar system efficiency issues.	Brainstorm practical applications of components in solar systems (e.g., diode for preventing backflow, transistor for switching).	Flipchart, markers
8. Present & Defend Solutions (5 min)	Facilitates Q&A and moderates presentations.	Present findings and defend solutions with reasoning.	Presentation tools
9. Reflect & Evaluate (5 min)	Summarizes main points, corrects misconceptions, connects lesson to broader electronics applications.	Reflect on learning, give peer feedback, and self-assess contributions.	Reflection sheets

Core Points	Evaluation	Remarks
Resistor: Limits or regulates current flow in a circuit; protects sensitive components. Capacitor: Stores and releases energy; smooths voltage fluctuations; used in timing/filter circuits. Diode: Allows current to flow in one direction only; used in rectifiers and protection circuits. Transistor: Acts as a switch or amplifier; controls large currents with small signals; used in radios, computers. How Diodes Work: Allow current flow only in forward-bias; block current in reverse-bias. Used in rectification, signal control, and protection. Transistor as a Switch: Small current at base turns on a larger current from collector to emitter. Transistor as an Amplifier: Small input signal produces larger output signal; used in audio devices and communication systems.	Explain how a diode works to protect electronic circuits. State one difference between the switching and amplifying function of a transistor. Describe one real-life application each of a resistor and capacitor.	…………………………………

WEEK SIX

General Objectives

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

1. Explain how semiconductors behave under different electrical conditions.
2. Compare AC and DC circuits in terms of energy efficiency, transmission, and use.
3. Use an oscilloscope to observe and differentiate AC and DC waveforms.

RPK

Students have already learnt about the functions of basic electronic components (resistors, capacitors, diodes, transistors).

Lesson Development (PBL Stages)

Week Ending: 16th May, 2025	Subject: Integrated Science	Time: 9:30-11:20am
Date: 13th May, 2025	Topic: Electronics	Duration: 100 minutes
Class: SHS 2	Sub-Topic: Semiconductor Behaviour and AC vs. DC Circuits	Class Size: 49
References	Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company. Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra.	

Step	Teacher Activities	Learner Activities	Resources
1. Identify/Present the Problem (5 min)	Shows a short video/visual of a school solar project. Poses the problem: 'Your school wants to use solar panels to power classrooms. Investigate	Listen attentively, ask clarifying questions, brainstorm possible	Whiteboard, markers, projector/video

	the differences between AC and DC circuits and determine which is best for the project.'	issues with solar power and current types.	
2. Clarify the Problem & Key Terms (5 min)	Gives a mini-lecture with student input on conductors, semiconductors, and insulators. Explains AC and DC basics.	Discuss in groups, define terms, and connect to prior knowledge.	Charts, textbooks
3. List What is Already Known (5 min)	Asks probing questions about conductors, current flow, and electronic devices.	Brainstorm and record what they know about AC, DC, and semiconductors.	Worksheets
4. Identify What Needs to be Learned (5 min)	Guides learners to ask questions like: 'How do semiconductors behave in different conditions?' 'Which current type is more efficient for classroom equipment?'	Formulate questions to guide exploration.	Worksheets
5. Assign Learning Tasks (Self-Directed Learning) (50 min)	Provides electronic components (diodes, resistors, LEDs). Demonstrates oscilloscope setup. Assigns groups to test and observe AC vs. DC characteristics.	In groups: Test semiconductor behaviour under different conditions. Observe AC and DC waveforms using an oscilloscope. Compare efficiency and suitability for classroom power systems.	DC power supply (batteries), AC power source, diodes, transistors, LEDs, resistors, oscilloscope
6. Share Findings & Discuss (10 min)	Facilitates group presentations, clarifies misconceptions.	Present findings, highlight differences between AC and DC circuits, and semiconductor behaviours.	Group reports
7. Generate Possible Solutions (10 min)	Encourages groups to apply knowledge to the solar classroom problem.	Recommend whether AC or DC is better, justify with evidence.	Flipchart, markers

8. Present & Defend Solutions (5 min)	Guides Q&A, moderates group defense of solutions.	Present and defend chosen current type for the classroom system.	Presentation tools
9. Reflect & Evaluate (5 min)	Summarizes lesson, links findings to real-world applications (solar panels, national grid).	Reflect on learning, provide peer feedback, and self-assess contributions.	Reflection sheets

Core Points	**Evaluation**	**Remarks**
Conductors: Allow electric current to flow easily. Examples: Copper, aluminum, silver. Semiconductors: Conductivity lies between conductors and insulators; can be modified by doping. Examples: Silicon, germanium. Insulators: Do not allow current to flow easily. Examples: Rubber, plastic, glass. Semiconductor Behaviour: At low temperatures act like insulators. At room temperature partially conductive. When doped, conductivity increases (n-type with electrons, p-type with holes). With heat/light, conductivity improves. AC (Alternating Current): Flows back and forth; from mains supply; used for transmission over long distances. DC (Direct Current): Flows in one direction; from batteries/solar panels; used in low-voltage devices.	Differentiate between conductors, semiconductors, and insulators with one example each. Compare AC and DC circuits under the following headings: a) Direction of flow b) Source c) One application of each. Demonstrate how to use an oscilloscope to observe AC and DC waveforms	…………………………………

APPENDIX M: Teacher-Centered (Lecture) Method Lessons Plan for the Control Group

WEEK ONE

Week ending: 11th April, 2025	Duration: 100 minutes	Subject: Integrated Science
Date: 10th April, 2025	Class: SHS 2	Topic: ELECTRICITY
Time: (9:25 – 11:05 am)	Class size: 46	Sub-topic: voltage, current, resistance and power

Reference: Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company.
Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra.
Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.

Objective/RPK	**Teacher-Learner Activities**	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
By the end of the lesson, students should be able to: Define voltage, current, resistance and power. State and explain the SI units of each electrical quantity. Describe the relationship between voltage, current, and resistance using Ohm's Law.	Introduction Teacher introduces the lesson by initiating a thought-provoking discussion by inquiring about the students' prior knowledge on electricity. Teacher Activities: Introduce the topic by defining voltage, current, resistance, and power. Explain each concept using board illustrations.	Whiteboard, markers	Voltage (V): Voltage is the electrical potential difference between two points in a circuit. It is the force that pushes electric charges through a conductor. Current (I): Current is the flow of electric charge through a conductor. It tells us how much charge passes a point in a circuit per unit time. Resistance (R): Resistance is the opposition to the flow of electric current in a conductor. It slows down the movement of charges.	Define voltage, current, resistance and power. What does Ohm's law state?

Students have learnt about simple electrical circuit components such as bulbs, batteries and switches in junior high school	Demonstrate simple circuits showing the role of voltage, current, and resistance. Provide real-world examples (e.g., voltage of a battery, resistance in wires). Solve sample problems on calculating voltage, current, resistance, and power. Assign practice exercises for students to attempt in class. Learner Activities: Listen and take notes during the explanation. Observe teacher demonstrations of voltage and current in a circuit. Ask questions for clarification. Solve example problems given by the teacher. Complete class exercises and submit for review.		Power (P): Power is the rate at which electrical energy is consumed or converted in a circuit. Ohm's Law states that the voltage across a resistor is directly proportional to the current flowing through it, provided the temperature remains constant V=IR Where: V is voltage (in volts), I is current (in amperes), R is resistance (in ohms).	

WEEK TWO

Week ending: 18th April, 2025	Duration: 100 minutes	Subject: Integrated Science
Date: 17th April, 2025	Class: SHS 2	Topic: ELECTRICITY
Time: (9:25 – 11:05 am)	Class size: 46	Sub-topic: Circuit Analysis Using Ohm's and Kirchhoff's Laws

Reference: Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company.

Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra.

Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.

Objective/RPK	**Teacher-Learner Activities**	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
By the end of the lesson, students should be able to: Explain Ohm's Law and its application in circuit analysis. State and apply Kirchhoff's Current and Voltage Laws. Solve circuit problems using Kirchhoff's and Ohm's Laws.	Introduction teacher briefly reviews key concepts from the previous lesson on voltage, current, resistance and power. Teacher Activities: Review Ohm's Law and demonstrate its application in simple circuits. Introduce Kirchhoff's Laws using circuit diagrams.	Whiteboard, markers	Ohm's Law helps calculate unknown values in a circuit. If any two of the three values (V, I, R) are known, the third can be calculated. It also allows us to predict how changes in resistance or voltage affect current. Kirchhoff's Current Law (KCL): The total current entering a junction equals the total current leaving the junction. $\sum I_{in} = \sum I_{out}$	A 12 V battery is connected in series with two resistors: (a) Calculate the total resistance

RPK Students have learnt about voltage, current, resistance and power in their previous lesson	Explain Kirchhoff's Voltage Law for series circuits. Explain Kirchhoff's Current Law for parallel circuits. Solve step-by-step examples involving Kirchhoff's Laws. Assign practice problems for students to work on in class. Learner Activities: Listen and take notes on Kirchhoff's and Ohm's Laws. Observe teacher demonstrations of circuit behaviour. Copy and solve example problems in their notebooks. Work in pairs to complete assigned circuit calculations.		Application: Used to analyze circuits with branches (parallel circuits) where current splits. Kirchhoff's Voltage Law (KVL): The total voltage around any closed loop in a circuit equals the sum of the voltage drops across each component in the loop. $\sum V=0$ Application: Used to determine unknown voltages or resistance in loops.	(b) Find the total current

WEEK THREE

Week ending: 25TH April, 2025	Duration: 100 minutes	Subject: Integrated Science
Date : 24TH April, 2025	Class: SHS 2	Topic: ELECTRICITY
Time: (9:25 – 11:05 am)	Class size:46	Sub-topic: Series and Parallel Circuit Calculations

Reference: Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company.

Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra.

Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.

Objective/RPK	**Teacher-Learner Activities**	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
By the end of the lesson, students should be able to: Explain the differences between series and parallel circuits. Calculate total resistance, voltage, and current in both circuit types. Identify practical applications of series and parallel circuits.	Introduction teacher briefly reviews key concepts from the previous lesson on circuit analysis using Ohm's and Kirchhoff's laws Teacher Activities: Define and explain series and parallel circuits using circuit diagrams.	Whiteboard, markers	The differences between series and parallel circuits Series Circuit: Components are connected end-to-end, forming one single path for current to flow. The current is the same through all components. The voltage is shared among the components.	A 12 V battery is connected in series with two resistors: (a) Calculate the total resistance (b) Find the total current

RPK Students have learnt about voltage, current, resistance and power in their previous lesson	Demonstrate how current and voltage behave in series vs. parallel circuits. Show the formulas for calculating total resistance in each circuit type. Solve examples step by step for series and parallel circuits. Provide real-life applications (e.g., home wiring, batteries in a flashlight). Give students sample questions to solve. Learner Activities: Take notes on series and parallel circuits. Observe the teacher's demonstrations of current and voltage distribution. Solve given circuit problems alongside the teacher. Complete additional exercises and discuss their answers.		If one component fails, the entire circuit stops working. Parallel Circuit: Components are connected across common points, forming multiple paths for current. The voltage is the same across each branch. The current divides across the branches. If one component fails, the others can still function. practical applications of series and parallel circuits Series Circuit Applications: Used where the same current must flow through each component. Example: Christmas tree lights (traditional type), torchlight circuits. Parallel Circuit Applications: Used in buildings and homes to ensure appliances work independently. Example: Household wiring when one light goes off, others remain on. Used in car electrical systems, power strips, and classrooms	

WEEK FOUR

Week ending: 2nd May, 2025	Duration: 100 minutes	Subject: Integrated Science
Date: 1st May, 2025	Class: SHS 2	Topic: ELECTRICITY
Time: (9:25 – 10:25 am)	Class size: 46	Sub-topic: Electrical Energy Consumption and Measuring Instruments
Reference: Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company. Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra. Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.		

Objective/RPK	**Teacher-Learner Activities**	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
By the end of the lesson, students should be able to: Explain electrical energy consumption and its unit (kilowatt-hour, kWh). Calculate the cost of electrical energy consumption. Identify and explain the functions of measuring instruments (ammeters, voltmeters, multimeters).	Introduction teacher briefly reviews key concepts from the previous lesson on Series and Parallel Circuit Calculations Teacher Activities: Explain electrical energy consumption and introduce the kWh unit.	Whiteboard, markers	Electrical energy consumption refers to the amount of electrical energy used by an appliance or device over time. It is calculated using the formula: Energy=Power×Time Power is measured in kilowatts (kW) Cost of electrical energy consumption	1.What is Electrical energy 2. A 2000 W (2 kW) heater is used for 30minutes per day for 3 days.

RPK Students have learnt about Electrical Energy Consumption and Measuring Instruments	Use real-world examples to show how to calculate power and energy usage of household appliances. Introduce measuring instruments and explain their roles. Demonstrate how to use a multimeter to measure voltage, current, and resistance. Learner Activities: Write notes on energy consumption and measuring devices. Observe teacher demonstrations of energy calculations. Ask questions about real-life applications. Solve sample power consumption problems.		Formula: Cost=Energy consumed (in kWh) ×Cost per unit (tariff) Example: A 1500 W (1.5 kW) heater is used for 4 hours per day for 10 days. Tariff: GHS 1.20 per kWh Energy used= $1.5\times4\times10=60$ kWh Cost: $60\times1.20=$GHS72.00 So, the cost of energy used is GHS 72.00	

WEEK FIVE

Week ending: 9th May, 2025	Duration: 100 minutes	Subject: Integrated Science
Date: 8th May, 2025	Class: SHS 2	Topic: ELECTRONICS
Time: (9:25 – 11:05 am)	Class size:46	Sub-topic: **Functions of Electronic Components (Resistors, Capacitors, Diodes, Transistors**

Reference: Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company.

Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra.

Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.

Objective/RPK	**Teacher-Learner Activities**	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
By the end of the lesson, students should be able to: Identify and describe the functions of resistors, capacitors, diodes, and transistors. Explain how diodes control current flow in a circuit. Explain the switching and amplification functions of transistors.	Introduction teacher briefly reviews key concepts from the previous lesson on Electrical Energy Consumption and Measuring Instruments Teacher Activities: Introduce common electronic components and their symbols.	Whiteboard, markers	Component Function Resistor: Regulates the flow of electric current in a circuit. It provides resistance and is used to protect sensitive components. Capacitor: Stores electrical energy in an electric field and releases it when needed. It smooths voltage fluctuations and is used in filtering and timing circuits. Diode Allows current to flow in only one direction and blocks it in	1. Explain how a diode works to protect electronic circuits. 2.State one difference between the switching and amplifying

RPK Students have learnt about Electrical Energy Consumption and Measuring Instruments	Explain the role of each component in a circuit. Provide real-world applications of each component (e.g., capacitors in fans, diodes in rectifiers). Demonstrate how a diode allows current to flow in one direction. Solve simple circuit problems involving resistors and capacitors. Assign textbook readings and exercises. Learner Activities: Listen and take notes on the properties and uses of components. Observe demonstrations of diodes and transistors. Ask questions to clarify concepts. Solve circuit problems related to resistors and capacitors.		the opposite direction. It is used in rectifiers and protection circuits. Transistor: Acts as a switch or an amplifier. It can control large currents using small signals and is used in electronic devices like radios and computers. How diodes control current flow in a circuit Diodes are semiconductor devices that allow electric current to flow in one direction When connected forward-biased (positive to anode), the diode conducts current. When connected reverse-biased (positive to cathode), the diode blocks current. This makes diodes useful for rectification (converting AC to DC), protecting circuits, and controlling signal flow in electronics. the switching and amplification functions of transistors transistor as a Switch A transistor can act as a switch by turning current on or off. When a	function of a transistor.

			small current is applied to its base, it allows a larger current to flow between the collector and emitter. This is used in digital electronics and logic circuits. Transistor as an amplifier A transistor can amplify a small input signal into a larger output signal. A small change in base current leads to a much larger change in collector current, making it useful in amplifiers (e.g., radios, microphones, and audio equipment).	

WEEK SIX

Week ending: 16th May, 2025	Duration:	Subject: Integrated Science
Date: 15th May, 2025	Class: SHS 2	Topic: ELECTRONICS
Time: (9:25 – 10:25 am)	Class size: 46	Sub-topic: Semiconductor Behaviour and AC vs. DC Circuits

Reference: Kusi-Aidoo, P. A. (2019). Integrated Science Revision Guide for Senior High Schools, Supporting Free SHS. Kumasi: Elite Publishing Company.

Ministry of Education (2010). Teaching Syllabus for Integrated Science (Senior High School). Accra.

Oddoye, E. O., Taale, K. D., Ngman-Wara, E., Samlafo, V., & Ofori, D. O. (2011). Integrated Science for Senior High Schools, Student's Book. Accra: Sam Woode Ltd.

Objective/RPK	**Teacher-Learner Activities**	**Teacher-Learner Resources**	**Core Points**	**Evaluation & Remarks**
By the end of the lesson, students should be able to: Explain the difference between conductors, semiconductors, and insulators. Describe how semiconductors behave under different conditions.	Introduction teacher briefly reviews key concepts from the previous lesson on Functions of Electronic Components (Resistors, Capacitors, Diodes, Transistors Teacher Activities: Explain semiconductor properties using the concept of electron flow. Illustrate how temperature affects semiconductor conductivity.	Whiteboard, markers	Difference between conductors, semiconductors, and insulators Conductors are materials that allow electric current to flow through them easily. Copper, aluminum, silver Semiconductors are materials whose ability to conduct electricity lies between conductors and insulators. Silicon, germanium. Insulators are materials that do not allow electric current to flow easily.Rubber, plastic, glass	1.Differentiate between conductors, semiconductors, and insulators. Provide one example of each. 2.Compare alternating current (AC) and direct current (DC)

Compare AC and DC circuits and their applications. RPK Students have learnt about Functions of Electronic Components (Resistors, Capacitors, Diodes, Transistors	Define AC and DC current and explain how they differ. Show practical applications (e.g., AC in power supply, DC in batteries). Demonstrate AC and DC waveforms using an oscilloscope. Assign problem-solving exercises on AC/DC applications. Learner Activities: Take notes on semiconductors and AC/DC circuits. Observe the oscilloscope demonstration of AC and DC waveforms. Compare real-life uses of AC and DC (e.g., home appliances vs. battery-powered devices). Complete a short quiz on the differences between AC and DC.		How semiconductors behave under different conditions At low temperatures: Semiconductors behave like insulators; very few charge carriers are available. At room temperature: Some electrons gain enough energy to move, making the material partially conductive. When doped (impurities added): Their conductivity increases significantly. n-type semiconductors have extra electrons (negative carriers). p-type semiconductors have extra holes (positive carriers). When exposed to light or heat: More electrons are excited, improving conductivity.	under the following headings: a) Direction of flow b) Source c) One application of each.