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Identifying and Dispelling Students' Misconceptions about Electricity and Magnetism Using Inquiry-Based Learning in Selected Junior High Schools

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ABSTRACT

This study was carried out among selected 80 Junior High School students in the Ashanti Region of Ghana to give answers to a misconception test dubbed *Electricity-Magnetism Inventory Test (*EMIT). The responses were graded and compared based on the pretest and posttest performances using simple descriptive statistics generated from the IBM SPSS software. The inquiry-based method of teaching was used to address the problem through a series of lessons designed on the concept of Electricity and Magnetism after which the EMIT was administered again to ascertain the efficiency of the intervention conducted. Findings from the data available indicated that students' misconceptions emanated from their socio-economic background, socio-cultural background, previous experiences that they encountered as they were growing up, and some lessons that were taught by teachers who thought them at lower levels. The misconceptions were largely cleared after they had been taken through the inquiry-based lessons. The study concludes that there the inquiry method is a panacea for dispelling students' misconceptions. The pretest results and the posttest results from the EMIT were evidence that misconceptions among students have been eliminated to a considerable level.

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1. INTRODUCTION

The dream of all 21st Century science teachers is to get their students to think critically, creatively, and innovatively while applying the concepts learned in science to solve the myriad of problems confronting them in their everyday lives. The vital changes in the economy, employment, and business are generating new, varied skill demands. More than ever, for someone to succeed, they need to be able to handle non-standard, creative jobs. The capacity to excel at non-routine work is no longer just rewarded; it is now anticipated as a basic prerequisite. While abilities like self-direction, creativity, critical thinking, and innovation may not be novel to the 21st century, they are freshly significant in this context. It is necessary to be able to think critically, solve issues, communicate, collaborate, obtain reliable information fast, and utilize technology successfully whether a high school graduate chooses to enroll in a university, community college, or vocational school. A trained workforce that is prepared for the major problems we face is necessary for reviving the economy, gaining energy sustainability through different technologies and decent jobs, and enhancing our healthcare system. However, there is general agreement that our educational institutions fall short in providing all students with the crucial knowledge and skills required for success in the 21st century, including those needed for success in life, the workplace, and civic engagement. However, these prospective workforces who are students today, enter classrooms with preconceived notions of how the world works.

Ashanti Region is one of the 16 regions in Ghana with a population of about five million four hundred and forty-three thousand, four hundred and forty-eight (5443448) people. It has 43 Metropolitan, Municipal, and District Assemblies (MMDAs) with diverse socioeconomic, and socio-cultural, experiences and educational backgrounds of the students. This means that the experiences, the socio-economic and socio-cultural background of Junior High School students selected from this population for the study vary in many learning experiences to a very large extent. Misconceptions about a concept or a procedure, are widespread and can occur in any discipline (Savion, 2009). Our experiences, which are sadly inadequate, serve as the foundation for our theories about the world and everything in it. As a result, our reasoning about why things function as they do is fairly limited. The teacher is however called to duty to ensure that the barrier to fully understanding the world is drastically reduced if not removed entirely. Teaching students for conceptual understanding requires a teacher who has the content knowledge, the pedagogy, and the pedagogical content knowledge.

The most interesting revelation is that teachers who know the misconception of their students are more inclined to assist them in learning science. Many researchers in science and other related fields have coined different names for misconceptions. Some have referred to it as "alternative frameworks," "alternative conceptions," "false meaning", and "intelligent wrongness", among others. Misconceptions represent the mind's attempt to relate new information to previous information stored in memory. The conceptual study of these students in various scientific concepts has been influenced by cognitive psychology-driven models which may be linked to the socioeconomic and sociocultural backgrounds of the students (Humphrey-Darkeh *et al* .2023).

Studies on the learning of science and for that matter physics, reveal that students enter their science classes with worldviews that diverge from those of mainstream science. Students' misconceptions and prior knowledge or ideas may interfere with learning during and after the learning process (Küçüközer & Kocakülah, 2007). It may also influence students' receptivity to new ideas (Arnold & Millar, 1987). When preconceptions are correct, these can

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be used as building blocks for conceptual understanding. But when these are wrong and persistent, they become obstacles to effective learning (Afra *et al*., 2009). According to Lilienfeld (2010), students could come across erroneous information, use flawed reasoning, or misinterpret what they read, hear, or see, leading to the development of misunderstandings.

Studies of science students' conceptual understanding and their misconceptions have become a central issue in science education due to their effects on students' learning for the past four decades (Halloun & Hestenes, 1985). This worry is justified because scientific literacy has emerged as one of the key ideas for approaching science in formal education that will help in attaining parts of the Sustainable Development Goals (SDGs) in health and wellbeing (SDG3). Those who advocate for universal scientific literacy frequently make the case that it is an essential quality of an informed, responsible citizen. In addition to the aforementioned pillars, it will not be out of place if one makes a statement that, the development of Ghana is largely hinged on how well its teachers tailor the science curriculum to suit its aims and objectives for which the subject is to be taught. This has further strengthened the case for much interest in the call for teachers to study students' prior knowledge in science and the relationship between students' prior knowledge and scientifically accepted principles. That is why much of the good science curricula attempt to bridge the gap between the imperfect knowledge of learners and the scientifically accepted principles.

Some students will not be able to learn ideas because the subject matter material may be at a level not commensurate with the student's developmental learning stage as well as the experiences that are available to build the enabling environment for learning. This student may cling to tenacious alternative conceptions which may arise due to some strange beliefs from the sociocultural background of the students; misconceptions that were not identified before instruction and considered during the stages of instruction. Curriculum, instruction, and assessment are significantly improved when teachers are aware of the developmental considerations and the research findings on commonly held alternative conceptions.
Misconceptions can be classified (see **Figure 1**) as follows:

(i) ***Preconceived notions*** are accepted beliefs that have their roots in daily life. For instance, a lot of people think that because they see streams of water on the surface of the earth, underground water must also run in streams. Students' perceptions of gravity, heat, and other concepts are all tainted by preconceived assumptions (Brown & Clement, 1989).

(ii) ***Non-scientific beliefs*** are opinions that pupils have acquired from non-educational sources such as religious or legendary teachings. For instance, some students have learned about a condensed history of the earth and its biological forms through religious ideas. There is a great deal of controversy surrounding the teaching of science because of the discrepancy between these generally believed views with the empirical evidence for a significantly longer prehistory. Non-scientific is not regarded as being the same as antiscientific, and the term is not used in a derogatory manner because there are many other ways to acquire knowledge. However, many science educators have discovered that non-scientific ideas can obstruct science learning, which, in turn, can prevent the generalization of science literacy (Losh *et al.* 2003; Martin, 1994). It is also worth noting that the use of the term "non-scientific" is being used to describe information that has not been obtained by using well-accepted scientific procedures or scientific instruments as suggested by Gauche. Nevertheless, what has come to be called lay theories are non-scientific misunderstandings. For instance, astrology has a set of principles and fundamental ideas that cannot be verified. Its predictions' ambiguity prevents falsification as a result of its hazy nature. The dependence on invisible forces to develop their explanations is a characteristic that unites non-scientific theories of the world. Additionally, there are no consistent practices across practitioners due to the lack of objective methods to measure or qualify these unknown variables or forces. As a result, their validity cannot be independently tested. The students in our classrooms have some of this type of misconception.

(iii) ***Conceptual misunderstandings*** are preconceived notions about what someone believes they comprehend based on their own experiences or possibly something they have heard. One does not fully comprehend and understand the concept. When students get scientific instruction in a way that does not force them to address the inconsistencies and conflicts brought on by their entrenched notions and non-scientific beliefs, conceptual misconceptions emerge. Students build flawed models to address their perplexity, which are generally so weak that the students themselves are unsure of the concepts.

(iv) Words that have one meaning in science and another in everyday speech might lead to ***vernacular misconceptions***. Words like "power," "wave," and "field," for instance, may be used in science class yet, have very different meanings in everyday life. The ordinary person sees power to be somebody in authority like political power or better still a person with a pack of externally healthy-looking muscles but at the same time, this is defined as the rate at which work is done. In the case of work, the layperson sees work to be a strenuous activity that requires sitting behind a computer or any activity that brings about an income to the person engaged in it. Meanwhile, the scientific definition of work is viewed as a force moving its point of application through a distance in the direction of the force.

(v) ***Factual misunderstandings*** are fabrications that are frequently picked up early in life and held onto until adulthood. People become aware of these factual errors over time because they are persistent. Although it is false, a lot of people may still believe that "lightning never hits twice in the same region," probably because it was imprinted in their belief system since they were young.

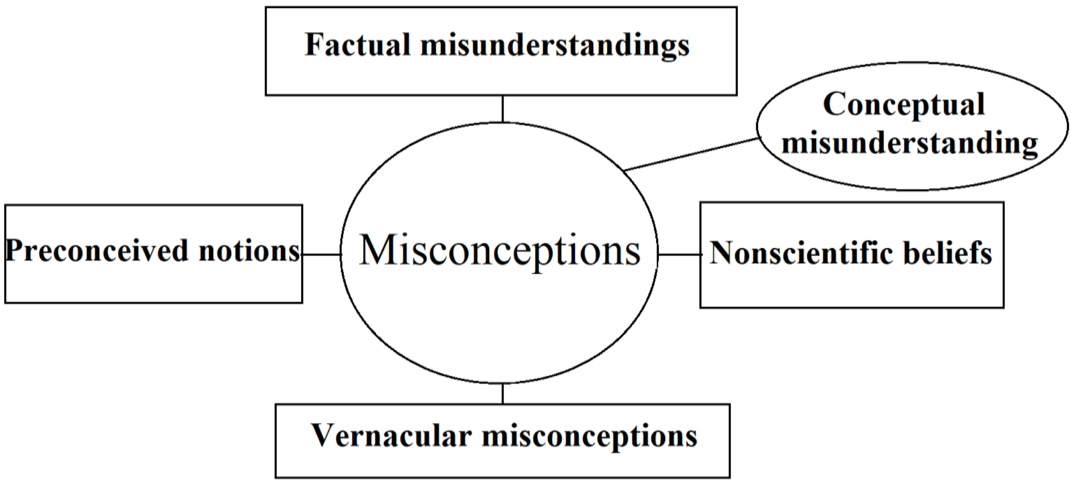

Figure 1. Types of Misconceptions.

Unfortunately, the students in our classrooms have an embodiment of all the forms of misconceptions enumerated above and teachers teaching science cannot gross over this. In a traditional class, the subject matter is nearly always delivered in a monologue fashion in front of a passive audience. This situation not only deepens the preconceived notions of students but also creates more barriers to discovery learning among students. Problem-solving, inquiry-based teaching as well as hands-on activity-based teaching has however been

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substantiated by literature as the most important way to master the material hence, overcome misconceptions. The truth of the matter is that students do not enter the science classroom as "empty vessels" waiting to be filled with scientific knowledge. According to constructivism, a theory of how people learn, students have a complex network of past beliefs and impressions about nature based on their own experiences, upbringing, popular culture, and interactions with others. Using traditional methods to deliver lessons in science to learners with misconception only benefits a few students who have experiences that are in tune with the scientific concepts they have learned to the detriment of the majority whose experiences are practically based on myths.

Besides, traditional teaching strategies which are usually teacher-centered have been claimed to be ineffective in developing students' conceptual understanding (Hake, 1998; Crouch & Mazur, 2001). Some studies reported that noticeable conceptual understanding changes in learners after being taught using traditional teaching methods were short-lived. Instead of being challenged by what has been learned during teaching periods, learners construct observations supporting their pre-teaching understanding (Mulhall *et al*., 2001). As students are active constructors of their knowledge (Arnold & Millar, 1987), student-centered teaching strategies help students construct knowledge on their own and enhance their conceptual understanding with a teacher as a facilitator.

At the primary, secondary, and tertiary levels of education, electricity, and magnetism are regarded as central subjects of physics and science curricula (Gunstone *et al*., 2009). Electricity and magnetism provide greater opportunities for practical investigations, including those for knowledge display and understanding through discussion and activity for children (Glauert, 2009). Additionally, applications of electricity and magnetism are found in many facets of our daily life. However, it has been noted that this subject of study contains many ideas where students form beliefs that diverge from those that are accepted scientifically.

Physics' ideas of electricity and magnetism are intricate and challenging to understand since their significance develops over a variety of phenomenological domains. Each of the phenomenological subfields adds a particular dimension to the concept's meaning. Force, energy, and work, as well as electric charge and current which are each different phenomenological sides of the field and which are also implicitly covered in instruction, are all topics that are covered in at least some classic physics textbooks that treat electricity and magnetism.

The fact of the matter is that electricity and magnetism can both be produced by electromagnetic induction and electromagnetism, respectively. The point is that a moving charge carries a magnetic field around itself indicating that electricity and magnetism are interwoven. In the Science curriculum being used by Junior High School students, Electricity is broken down into sources, uses, conductors, semiconductors, and insulators, as well as components of simple circuits, series circuits, parallel circuits, and Ohm's law and its applications, in the basic school curriculum. Moreover, the components of magnetism being treated are making magnets, electromagnets, hard and soft magnets, breaking magnets, magnetic fields, and the first law of magnetism. When teaching these ideas, teachers run into many misconceptions that, if left unaddressed, can become very concerning as students move up the academic ladder.

One way to find misconceptions is to utilize a multiple-choice test, which most students are accustomed to. It is simple to rate and provide information about how students learn and what they value in their studies when you assess them with multiple-choice questions. However, it is unable to delve as deeply into what they know as interviews will do. To maximize the benefits and reduce the negatives of the two approaches, it may be beneficial

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to combine them (Engelhardt & Beichner, 2004). Interviews can be used in addition to the multiple-choice test's speed and objectivity to gather the in-depth information required. However, scheduling interviews for this requires skilled teachers and takes time. In multiple-choice tests that were objectively scored, Engelhardt & Beichner (2004) asserts that the ability to statistically analyze data from a significant sample of participants may boost the generalizability of the results. Some students achieve great marks despite not fully grasping some fundamental scientific principles. It has also been stated that a significant portion of pupils in many poor nations does not acquire the essential conceptual understanding when challenged to solve physics-related tasks.

These students try only to memorize mathematical formulas that are physics related. Learning is not simply the acquisition of a set of correct responses. Instead, learning is a process of conceptual growth and change (Posner 1982). As a result, students who have a strong conceptual grasp of physics, as well as problem-solving abilities, will be able to connect key material to what they already know rather than simply remembering it as it is delivered. Students must therefore be helped to build their conceptual grasp of physics so they can relate physics to the actual world, as well as their problem-solving abilities (Hake, 1998). One of the proposed remedies for students' misconceptions about electricity and magnetism is the identification and clarification of students' past knowledge and misconceptions. This is done by using questionnaires before the introduction of electricity and magnetism lessons. This strategy allows educators to explain related concepts with correct reasoning to help students to get rid of those misconceptions. The success of this approach requires good content knowledge on the topic for educators, libraries, and well-equipped laboratories. Utilizing this method allows teachers to more effectively help students overcome their preconceptions while guiding them toward acquiring scientifically accepted concepts (Turgut *et al*., 2011).

While using an outmoded teaching strategy, it is not easy to provide enough opportunities for students to critically think in the process of developing arguments. Problem-solving is reinforced by facilitators as the most important way to master the material. Many scientific topics have proven to be favorable to learners in most learner-centered classrooms. Inquiry-based learning (IBL), project-based learning, and laboratory methodologies, among others, have all influenced the conversation in classrooms. Students are now active participants in the learning environment thanks to these methods, which have brought education to their doorsteps. The advantages of these strategies do not pertain to only the full participation of students but have also aligned themselves to dispelling misconceptions of learners in the science classrooms.

One of the comprehensive survey tools created in 2001 by Maloney *et al* to gauge students' knowledge of electricity and magnetism is the Conceptual Survey of Electricity and Magnetism (CSEM). Recognizing that a problem exists is the first step toward solving it. If misconceptions are discovered during a learning circumstance, it is the teacher's responsibility to use the most straightforward approach to assist the students in dispelling their preconceptions. Understanding students' potential misconceptions and prior knowledge is necessary for the effective application of instructional strategies that assist students in overcoming their preconceptions (Turgut *et al*., 2011). Before teaching a new concept to students, teachers must ascertain the past knowledge and misconceptions of the class. It is also better for the teacher to identify the most effective teaching methods that will help overcome students' misconceptions (Maloney *et al*., 2001; Abdullah & Limb, 2012; Villarino, 2015; Uwizeyimana *et al*., 2018).

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It has also been established by Afra *et al*. (2009) that to improve students' understanding of electricity and magnetism, constructive methods such as IBL and problem-based learning (PBL) have been suggested. Constructivism incorporates elements of Piagetian and Vygotskian learning theories, particularly the significance of identifying prior knowledge or previous cognitive frameworks to guide conceptual development, which may explain its growing popularity as a teaching technique (Cakir, 2008). According to Cakir (2008), conceptual change can be described by the notions of recognizing, evaluating, and reconstructing. The individual must accept the existence and nature of their current beliefs, decide whether to consider them valuable and useful, and whether or not to reconstruct them (Cakir, 2008). Posner *et al*. (1982) at Cornell University created a model of conceptual change that describes learning as a process in which a learner modifies his or her conceptions by capturing new conceptions or exchanging previous conceptions for new ones (Posner *et al*., 1982; Cakir, 2008). According to research, learning involves similar patterns of conceptual change.

It must be emphasized that the assessment of students' prior knowledge and misconceptions about a topic before it is taught can help teachers to prepare lessons and strategies to help students to address their previous misconceptions about the subject matter. Teachers have to allow their students to deal with their initial knowledge and help them formulate a qualitative understanding of currently accepted physics concepts or expert views. Needlessly, students need active participation in constructing their knowledge into a consistent global structure. Thus, the focus of IBL is on the student's participation in the learning process. Students are urged to study the subject, ask questions, and exchange ideas rather than having the teacher dictate what they should know. Small-group discussions and guided learning are two methods of instruction used in IBL. Students learn by doing rather than by memorization of information and knowledge. They can use inquiry, experience, and conversation to increase their knowledge in this way. IBL actively involves students in the learning process, just like experiential learning does. The benefits of IBL may include but not limited to;

(i) Enhances learning experiences for children. Sitting in a classroom and taking notes is not always the most effective (or fun) way to learn. rather than memorizing facts from the teacher, IBL enhances the learning process by letting students explore topics themselves.
(ii) Teaches skills needed for all areas of learning. As they explore a topic, students build critical thinking and communication skills. The cognitive skills that students develop can be used to improve comprehension in every subject, as well as in day-to-day life.
(iii) Fosters curiosity in students. An IBL approach lets students share their ideas and questions about a topic. This helps foster more curiosity about the material and teaches skills students can use to continue exploring topics they are interested in.
(iv) Deepens students' understanding of topics. Rather than simply memorizing facts, students make their connections about what they are learning. This allows them to gain a better understanding of a topic than they would get by just memorizing and recalling facts.
(v) Allows students to take ownership of their learning. Students have the opportunity to explore a topic, giving them more of a sense of ownership over their learning. Instead of the teacher telling them what they should know, students can learn in a way that works for them.
(vi) Increases engagement with the material. As a form of active learning, this approach encourages students to fully engage in the learning process. By allowing students to

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explore topics, make their connections, and ask questions, they can learn more effectively.

(vii) Creates a love of learning. IBL is designed to teach students a love of learning. When students can engage with the material in their way, not only are they able to gain a deeper understanding; they can develop a passion for exploration and learning.

It is wort h noting that the study is not concerned with content delivery, the focus of this study is to show how pedagogy can influence a positive behavior change.

The theoretical framework of this study is based on the diagram in **Figure 2**. The theoretical framework above obviously a constructivist approach to learning is supported by the five Es of learning namely engage, explore, explain, elaborate (extend), and evaluate. The experimentation stage is where students are engaged with the teaching and learning material for them to explore and come out with their findings. From here many of the difficult concepts that hitherto were not understood by the students during their engagement with the TLMs are explained to them by the facilitator for them to conceptualize what they have learned. When prior knowledge is accurate, rich, and well-organized, it can help students learn and retain new information. By asking learners to build on their understanding, we can situate what we are teaching them in the context of the relevant knowledge they already have. As students grow, they develop conceptual frameworks to explain their observations of the natural phenomena that occur around them.

These conceptual frameworks are often intuitive. Conceptual change is a process that changes or replaces an existing conception with a new conception. It could be an idea, a belief, or a way of thinking. To solve present problems and explain the knowledge, the change creates a conceptual framework (Posner *et al*., 1982). In conceptual change learning, an existing conception might be fundamentally changed, replaced, or assimilated by new knowledge. This gives them many experiences that they can relate to in society hence they will be able to extend what they have learned to cover similar occurrences or experiences. Following the observations made through the experiments that led to conceptual change, students will now apply the experiences they have gained in similar situations to solve societal problems. Invariably, the sense of evaluation will be sharpened. Subsequently, they will be fit for purpose for the workforce required in the 21st century.

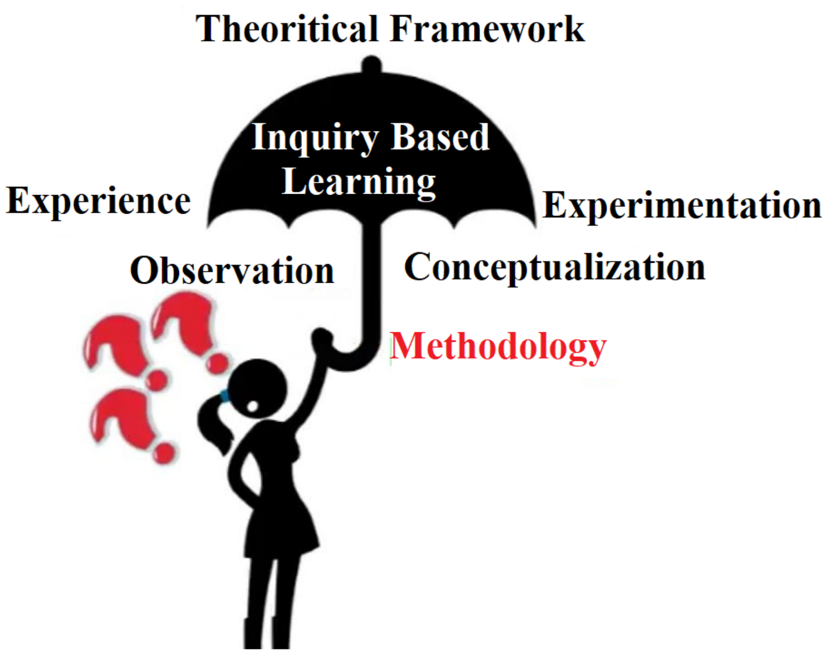

Figure 2. Theoretical Framework Model on IBL.

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Electricity and magnetism as fundamental areas and significant topics in science have applications encompassing many aspects of our everyday life. However, this area has been reported to have several concepts in which students develop views that are different from those accepted scientifically. During our observation in s some selected schools in the Kumasi Metropolis of the Ashanti Region, we realized that the concept of electricity and magnetism posed a big challenge to the students in most of the Junior High School classrooms where we sat. This problem was however traced to many misconceptions that most of the students had about the topic as it was evident in the kind of answers that the students gave to questions posed by the class teachers

Students depend on misconceptions in science subjects particularly at the beginner level. Before beginning their science lessons, they already held some false beliefs (Clement, 2006). Experiences are important in the teaching of science, particularly in the beginning (Hestenes *et al* 1992). Usually, this experience forms the foundations of the misconceptions that students have. Higher-class misconceptions could develop from unrelated ideas and merge with an advanced mental framework.

The purpose of this study was to identify the misconception of the students about electricity and magnetism and to help the students to conceptualize the concept of electricity and magnetism using an activity-based method of teaching called IBL. The research was guided by the following research questions;

(i) To what extent has the misconception of students in Electricity and Magnetism affected their performance in science?

(ii) What are the sources of students' misconceptions about Electricity and Magnetism?

Hypotheses are explained in the following:

(i) **H1**: *There is a difference in conceptual understanding of electricity and magnetism among learners when IBL is used to teach.*

(ii) **H0:** *There is no significant difference in the conceptual understating of electricity and magnetism among learners when IBL is used to teach.*

2. METHODS

The study did not only aim at exposing the misconceptions of students in electricity and magnetism but also to help in minimizing the misconception through IBL. The study adopted the action research design.

Eighty (80) students, ten (10) from each school were purposively sampled from 8 schools in the Ashanti Region without prejudice. The selection was done based on proximity but was primarily targeted at schools with semi-well-endowed learning environments and located largely in the Municipals. The aim was to capture students' whose learning conditions were between the well-endowed; those in the metropolitan Assembly and the less-endowed; those in the districts. These groups of students share some basic commonalities library books, subject-specific teachers, timely and adequate supply of textbooks, etc. found in the well-endowed schools and the less-endowed schools.

The Electricity-Magnetism Inventory Test (EMIT) (Hestenes *et al.*, 1992), which consists of 10 multiple-choice questions related to some misconceptions in Electricity and Magnetism concepts, was adopted and used as a pre-and post-test in the study. In this study, internal reliabilities for the pre and post-test (Kuder-Richardson 21) were calculated as 0.67 and 0.69, respectively. For a test containing correct or incorrect answers, the dependability is determined using the Kuder-Richardson Formula (KR20 or KR21) (binary variables). To create a case for internal validity, and reliability, the ability of an instrument to measure a construct consistently must be empirically proven. The estimation of reliability is based on the

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percentage of the measure's variability that can be attributed to the true score. Reliability is defined as the consistency and stability of a measure. It reveals how effectively the test captures the anticipated outcomes. The reliability estimates for the EMIT imply that scores obtained on this test are reliable and valid in measuring students' understanding of concepts of electricity and magnetism.

The data collection procedure in this study was divided into two sessions, data were obtained at the preintervention stage after the EMIT was administered to the students. This helped us to identify the misconceptions among the 80 students who were purposively sampled for the study. The post-intervention stage also collected data for this study; after going through the lesson with the students, the students were made to take the EMIT test again, this was to check the impact of the pedagogy on the conceptual understanding of the students.

Peters (1984) observed a lot of misunderstanding among the students when he asked them how the brightness of each bulb changed after connecting a wire between A and B as illustrated (**Figure 3**). In general, students find these kinds of two-loop circuits with induced electromagnetic fields (EMF) to be highly perplexing. Romer (1982) made the essential observation that when there are induced EMFs, the topology of the circuit is crucial, as opposed to typical dc circuits, which can be distorted in any way as long as the elemental ordering is maintained. In this study, students' misconceptions about electricity and magnetism were detected in the following areas after they had taken the EMIT at this stage of the study. Students had problems stating the functions of the components of the circuit. It was also detected that students did not understand the concept of current, voltage charge, and power. Furthermore, students were of the view that all metals were magnetic and could be magnetized. Lastly, it was also realized that students' idea about the poles of a magnet when broken sparks off a great deal of misconception. They believed that magnetic poles could be separated by breaking them. The above misconceptions were those that were addressed through inquiry-based teaching.

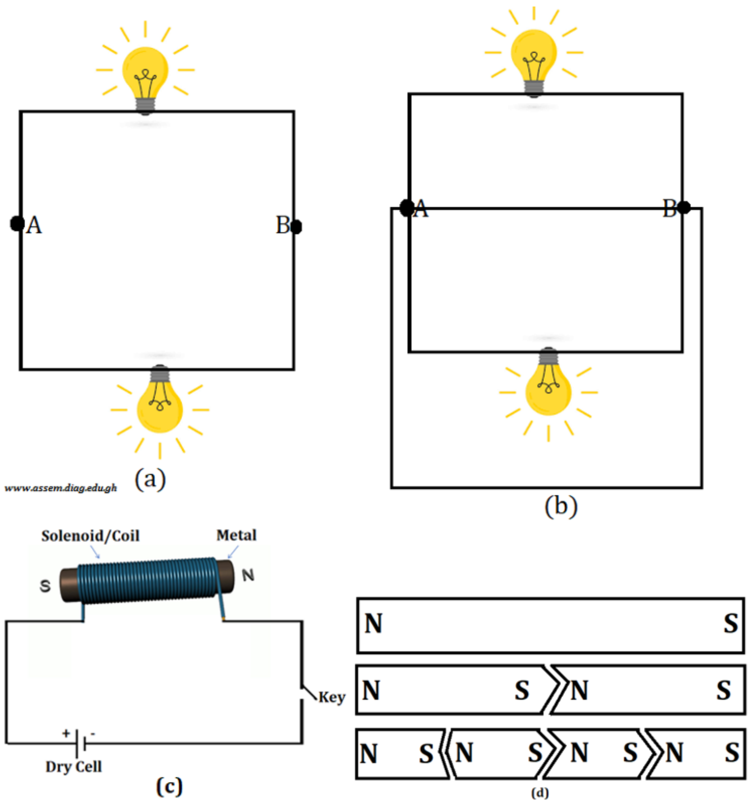

Figure 3. Electrical and Magnetic Circuits Misconceptions Among Students.

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The pre-test on the EMIT was given to the students during the first week of the study in the school to determine the number of students who have misconceptions and also to identify which teaching method could solve the problem. The move also allowed us to ascertain the entry behavior of the sampled size. Following the delivery of the pre-test, the answers provided by the students were scored on a 10 points scale. The mean score for the class was determined after the pre-test was scored. The students' pre-test results further demonstrated that they had misconceptions regarding electricity and magnetism. To remedy the problem, students were scheduled for four weeks of teaching and learning at two hours per day and four days a week.

The misconception of students regarding electricity and magnetism was addressed using lessons in electricity and magnetism designed around the inquiry method of teaching and learning science. Lesson plans followed the five Es of teaching; engage, explore, explain, extend (elaborate), and evaluate to confirm the theoretical framework of this study.

The lesson plan was designed in phases aimed at remedying each identified misconception. The sub-topics under consideration were:

(i) Electric charge, electric current, and voltage
(ii) Magnetism and magnetic poles
(iii) Magnetic substances and non-magnetic substances

The lessons in each case followed the same pattern as explained:

(i) Engage:
- Secure the prior knowledge of students through questions
- Provide students with the objectives of the lesson
- Stimulate the interest of learners by heightening their expectations as well as your excitement if they can achieve the targets set. Set out clear areas which will attract extrinsic motivation

(ii) Explain:
- Provide learners with TLMs or where to get the resources
- Let students know what they are expected to do and what they are expected to learn from it.
- Explain the grey areas of the activities that students are supposed to engage in with safety precautions outlined

(iii) Explore:
- Provide learning experiences of the topic under investigation for students to explore
- Guide students to interact with the TLMs with a set of questions that they are supposed to inquire into and with the objectives aligned.
- Get students to present their findings
- Punch constructive holes into findings presented by students while posing probing questions to more inquiries till the lesson is over. Supervision is key here.

(iv) Elaborate/Extend:
- Create situations where learners will apply what they have learned. If possible, organize a trip where knowledge gained in the lesson is applicable for more consolidation.
- Touch on points they failed to explain properly and make outstanding observations from activities carried out by students

(v) Evaluate:
- Review the lesson and evaluate what has been done
- Ask students to support the responses to the assessment question with evidence of work done.

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- Create space for reflection on what has been learned identifying strengths, weaknesses as well as areas that need improvement.

Below is a sample lesson plan for one of the lessons
Topic: Electricity and Magnetism
Sub-Topic: Electric charge and electric current
Relevant previous knowledge:
Pupils turn on switches in their homes which cause bulbs to light up in their homes
Objectives: By the end of the lesson, a pupil should be able to;

- Explain electricity
- Identify electric charges
- Define charge, current, and voltage
- Write the relation between electric current and electric charge

TLMs
Dry cell, connecting wires, bulb, key
Teacher-Learner Activities
Engage:

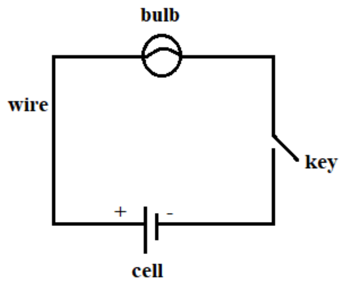
- The teacher reviews students' relevant previous knowledge by asking students to come out with how bulbs are light up in their homes

Explain:

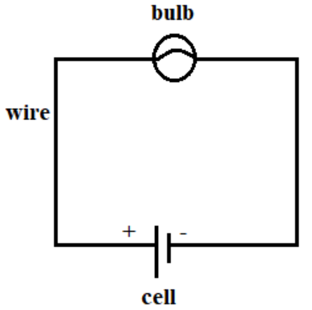
- Provide students with the objectives of the lesson
- Teacher Provide learners with cells, bulbs, connecting wires
- Provide students with a working diagram.

Explore:

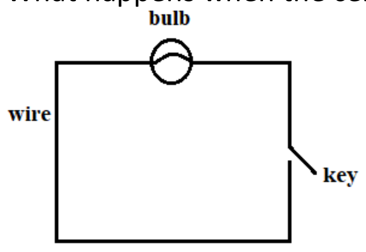
- Connect the bulb to the wires and then to the cell as shown in the diagram



- What happens when the key is closed



- What happens when the cell is removed



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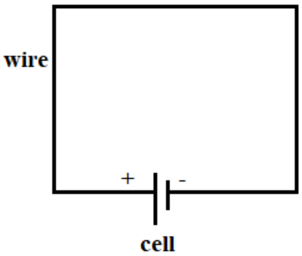
- What happens when the bulb is removed?



For the Connection of simple circuits, students should refer to the following:

- Get students to present their findings
- Let students explore the internet to get the meaning of electricity, charge, current, and voltage.

Elaborate:

- Identify devices in the environment/home that work in a like manner to the circuit
- Identify other sources of electricity apart from the cell.

Evaluation:

- Write a simple relation for the charge, current, voltage, time, and electric energy

The post-test was used to determine whether the students' misconceptions about electricity and magnetism had been dispelled after the intervention. The fifth week of the study was spent administering the post-test on the EMIT. The Inventory test on EMIT that was used in the pretest was employed but with a new layout. Some of the words were modified to make them appear new. Scripts from the students were collected and marked.

The means, standard deviations, and variance of the two EMITs were used to analyze the data gathered to respond to the research questions. The discrepancies between the student's performance in the electricity and magnetism inventory test at the pretest and posttest were highlighted. Using IBM SPSS software, the means and standard deviations as well as the one sampled tailed test (T-test) were analyzed and conclusions were drawn.

3. RESULTS

The data have been analyzed taking into consideration the research questions that have necessitated this research.

3.1. Research Question One: To What Extent has The Misconception of Students in Electricity and Magnetism Affected Their Performance in Science?

This research question was answered using the pretest and posttest results obtained by the 80 students. The ensuing tables present the results (see **Table 1**).

Table 1. Frequency Table for Pretest.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	2	1.3	2.5	2.5
	2	34	22.7	42.5	45.0
	3	25	16.7	31.3	76.3
	4	13	8.7	16.3	92.5
	5	6	4.0	7.5	100.0
	Total	80	53.3	100.0	
Missing	System	70	46.7		
Total		150	100.0		

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The research question above has been answered through descriptive statistics below. **Table 1** shows the performance of the students before the intervention was carried out. It was recorded that the least mark obtained was 1 representing 1.3% of the sampled size. This mark was obtained by two students. Thirty-four students representing 22.7% obtained 2 out of a total of 10 marks awarded to the EMIT. Also, it can be observed from the table that twenty-five students representing 16.7% of the sample size of eighteen obtained 3 marks out of 10. Again, thirteen students representing 8.7% obtained 4 marks each. It is worth noting that half of the 10 marks were obtained by 4.0% of the total sample size. No student obtained any mark above 5 in the pretest. This showed that the level of misconception was alarming. The information above has been graphed on the histogram below (**Figure 4**).

Table 2 depicts the performance of the students after the intervention was implemented. It was recorded that the least mark obtained was 4 representing 9.3% of the sampled size. The score was obtained by 14 students. Nine students representing 5.6% obtained 5 marks out of the total mark of 10. Also, 14 students representing 9.3% of the sample size of eighty garnered 6 marks out of 10. Eighteen students representing 12.0% scored 7 marks while seventeen students representing 11.3% obtained 8 marks. Eight students out of the 80-sample size obtained 9 out of 10 marks and finally. This figure represents 5.3% of the sample size. The performance from the post-test revealed that students' misconceptions had been largely dispelled. It also shows how effective the inquiry method has been. The information above has been illustrated in the histogram (**Figure 5**).

Table 3 has the values of the standard deviation and the variance of each test. The skewness and Kurtosis of marks have been clearly illustrated in the table. Comparing the standard deviation values; 0.987 for the pretest and 1.607 for the post-test shows a better performance of the students after the intervention.

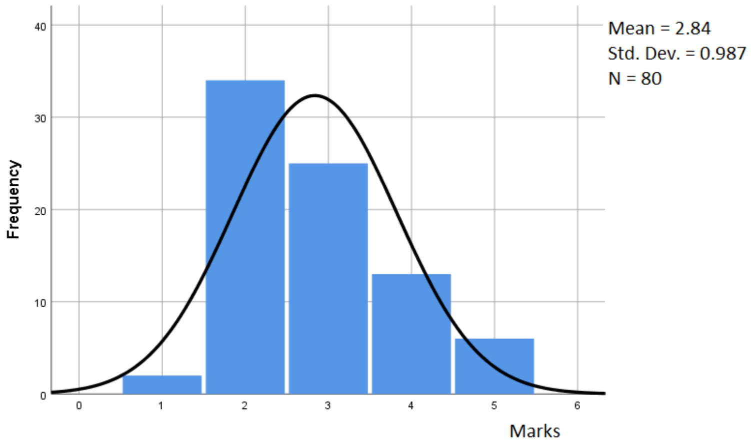

Figure 4. Histogram of Pretest Scores.

Table 2. Frequency Table for Posttest.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4	14	9.3	17.5	17.5
	5	9	6.0	11.3	28.7
	6	14	9.3	17.5	46.3
	7	18	12.0	22.5	68.8
	8	17	11.3	21.3	90.0
	9	8	5.3	10.0	100.0
	Total	80	53.3	100.0	
Missing	System	70	46.7		
Total		150	100.0		

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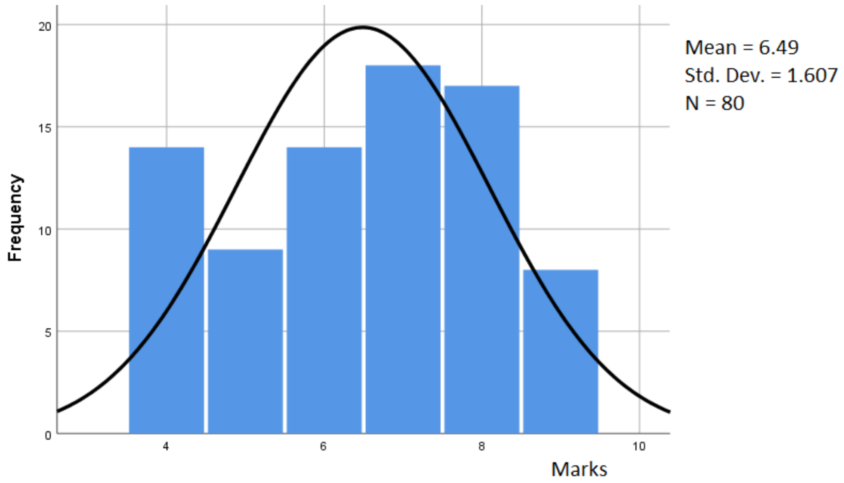

Figure 5. Histogram of Posttest Scores.

Table 3. Statistics on Both Pretest and Posttest.

		Pretest	Posttest
N	Valid	80	80
	Missing	70	70
Mean		2.84	6.49
Median		3.00	7.00
Mode		2	7
Std. Deviation		.987	1.607
Variance		.973	2.582
Skewness		.660	-.183
Std. Error of Skewness		.269	.269
Kurtosis		-.313	-1.090
Std. Error of Kurtosis		.532	.532
Range		4	5
Minimum		1	4
Maximum		5	9

From **Tables 4** and **5**, the one sample-tailed test shows that there was a significant difference between the performance of students in the pretest and the posttest kind courtesy of the intervention. This happened at a confidence interval of 95% for the upper and lower limits. Hence the null hypothesis is rejected.

Table 4. One-Sample Statistics.

	N	Mean	Std. Deviation	Std. Error Mean
Pretest	80	2.84	.987	.110
Posttest	80	6.49	1.607	.180

Table 5. One-Sample Test.

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Pretest	25.726	79	.000	2.838	2.62	3.06
Posttest	36.111	79	.000	6.488	6.13	6.85

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3.2. Research Question Two: What are the Sources of Students' Misconceptions About Electricity and Magnetism?

Over the years, there has been a lot of research on how to deal with misconceptions. The source of one's misconception determines how the misconception can be handled and dealt with. Although there is an ongoing dispute on the subject of how misconceptions come about, the majority of those involved in science education agree with the position taken by Posner *et al*. (1982). This hypothesis holds that students do not have any motivation to alter their worldview as long as it helps them solve problems. This means that if the misconception that students hold emerges from the society in which they dwell and this misconception helps the student to solve his or her problems then it will be difficult for the person to do away with it. However, if a learner is not happy with their initial thought, they may discard it and a conceptual transition may take place.

The students that teachers teach come from various backgrounds with different sociocultural and socioeconomic backgrounds. Their constant interaction with these environments forms the basis for the generation of ideas that linger on in their private lives. Such discontent may be brought about by discrepancies between the student's perspective and the results of the experiment (Driver *et al*., 1994). However, a student's initial reaction to anomalous facts is not always a rejection of conventional wisdom. Another source of students' misconception has been the way and manner teachers cite examples in their respective classrooms. In the case of electricity, a teacher who mistakenly uses the phrase "half or full current" instead of saying low or high current is likely to imbue in learners a long-lasting misconception that students will grow with.

The examples we give students especially when we want to make it simpler for better understanding have always been taken by students as the actual concept we intend to deliver. Another example that can be cited in the field of magnetism is when a teacher tells students that *magnets are like spirits* that we do not see and so act invisibly. Teachers who use these types of examples create a link in the minds of student that establish a relationship between the real world and the supernatural world. Unfortunately, teachers do not get to teach their students forever. This means that even if the student repeats this misconception elsewhere, the likelihood of a crash of concepts is eminent. Before conceptual transformation is established, there are a few more prerequisites. First, a fresh hypothesis needs to exist. Additionally, the new idea the student encounters must be understandable, reasonable, and useful for problem-solving (Posner *et al*., 1982). Although this theory has undergone numerous improvements and additions over the past thirty years, its basic tenet continues to enjoy widespread acceptance. It will not be taken into account. The sources of learners' prior knowledge (**Figure 6**) in science lessons can be obtained from;

(i) A previous lesson that has a link with the new lesson to be taught
(ii) The socio-cultural background of the students that may include their geographical location and other traditional activities that they engage in.
(iii) The socio-economic background of the students. students who come from affluent homes are more likely to be abreast with modern technology than students who come from poor or even average homes.
(iv) Experience of the learner. Learning a new concept is largely dependent on the experience that the learner encounters. If the experience is favorable, the learner is more likely to retain its effects for a very long time.

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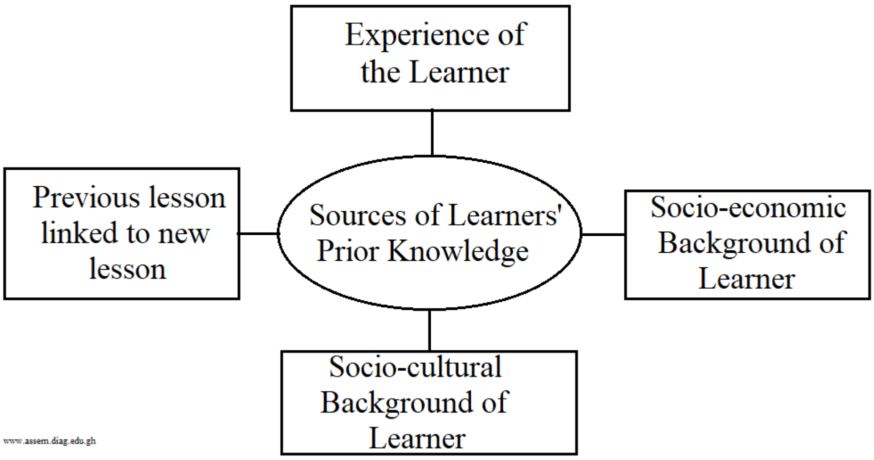

Figure 6. Sources of Learners' Prior Knowledge.

The view that these same sources of learners' prior knowledge can also be the sources of misconception. The variation theory, a modern theory of learning put out by Marton and Booth, appears to provide the theoretical basis for how pupils learn to understand concepts. Difference theory, the most recent advancement in the history of phenomenography is a variation theory. The goal of phenomenography is to "disclose the various ways in which individuals experience phenomena". In turn, variation theory explains precisely how students begin to comprehend phenomena. According to variation theory, every idea or phenomenon has important components that set it apart from similar ideas. For instance, to comprehend the concept of "cell in electricity," one must get familiar with such important elements as their function and purpose else a mere mention of it will suggest a different meaning to others who are familiar with the living cell or even a police cell. It is worth noting here that teachers must begin to identify these sources of misconception and take stringent steps to address them.

4. DISCUSSION

Beliefs that go against the body of available scientific data are known as misconceptions. They may or may not be the consequence of ignorance, but more often from a worldview that upholds a specific misperception and discourages the exploration of different viewpoints that would undermine it. The proper knowledge of a discipline is taught to the pupils through traditional teaching. We refer to this as stating the obvious facts or proof, or "right is right." During this type of teaching, we might first explain to our pupils what a concept means. For example, electricity is a form of energy associated with charges that can be stationary or mobile as in static electricity and current electricity. By this definition, the teacher has provided evidence and explanation but has yet to address the misunderstanding of the students.

The question remains why would he/she not start by addressing the misconception of the students? A growing body of research indicates that if you start with the misconception, students who are aware of it and believe it is more likely to tune you out. This is especially true of students who strongly believe it or who have trouble keeping up with the constant flow of information in the classroom. Students can repeat what you said if you ask them right away, but this new information soon returns them to their earlier errors. Some research has discovered a "familiarity backfire effect" where pupils' confidence in the fallacy grows stronger. This first thing students hear i.e., misconception sticks in their minds, and the rest of the lecture is forgotten. So always start with the facts before moving on to the myth. The

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solution to this in addition to starting with the fact is the use of the IBL method of teaching. Given the sources of students' misconceptions as their experiences, the socio-cultural, and socio-economic backgrounds, and a previous lesson taught by teachers, it is only the inquiry method that can dispel their preconceived ideas.

The advantages of the inquiry method outweigh many of the teaching methods available for the teaching and learning of science. It has been said time and again that inquiry methods help learners to take ownership of their learning. It unearths hidden potentials in students and then encourages them to seek more clarifications on issues about causes and their effects. As educators, we want all of our students to leave our classes knowing the truth or better still acquiring scientific concepts devoid of flaws. Unfortunately, there are false beliefs in every field of study; educators should not dismiss them. No matter what else you do for the course, studies regularly demonstrate that if you do not actively engage with and challenge misunderstandings, they do not go away. At best, incorrect knowledge will coexist alongside misconceptions. They will, at worst, prevent kids from learning new things.

5. CONCLUSION

The conclusions of this study are limited to the school under investigation due to the limited nature of the geographical size as well as the sample size. The study concludes that there was indeed a significant difference between the pretest and posttest scores at a confidence interval of 95%. The pretest results and the posttest results from the EMIT were evidence that misconceptions among students have been eliminated to a considerable level. This is partly attributed to the fact that the inquiry-based approach to teaching had significantly impacted the conceptual changes of the learners. It should be noted that the performance as per the two means indicates that the posttest mean score was around 6.49 in contrast to the pretest mean which was around 2.84. Their scores spread out much farther from their mean. Although the material presented to the students was the same, the results of the posttest reveal a significant difference between the performance of students in the two tests. This study has made many recommendations which when adhered to by policymakers, curriculum implementors, and government could aid decision-making processes to facilitate a smooth implementation of a curriculum. These include:

(i) Students should be allowed to study in an environment that requires that they freely interact with TLMs while teachers play the facilitating role to enhance teaching and learning. Students can forgo their misconceptions when teachers can investigate their prior knowledge before instructional materials and course contents are given to them.
(ii) Teachers must focus on areas such as previous lessons, the socioeconomic backgrounds of students, and the sociocultural background of students to explore their prior knowledge for a given lesson. This way, students' misconceptions can be identified and rightfully corrected.
(iii) The cost of running an IBL is quite costly hence, the Government of Ghana must support teachers logistically in the areas of teaching and learning materials for effective delivery.
(iv) In-service training should be organized for teachers on the job for effective use of the IBL.

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7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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